New Scientist

WEEKLY 3 February 2024

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NASA'S TOP TARGETS IN SEARCH FOR ALIEN LIFE

AI LEARNS BETTER IF IT 'SLEEPS' LIKE HUMANS

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Virtual event

The road to conscious machines

Public debate about artificial intelligence often centres on the idea of a dystopian robot takeover. Michael Wooldridge, a computer scientist at the University of Oxford, will instead explore how our anxieties distract us from the immediate risks this technology poses – from algorithmic bias to fake news – revealing the real, life-changing potential of AI. This subscriber-only event takes place on 12 March at 6pm GMT/1pm EST.

newscientist.com/events

Tour

Total solar eclipse 2024: Texas, US

Experience the magnificent solar eclipse that will take place across North and Central America next year. Join *New Scientist* features editor Abigail Beall on a visit to NASA's Space Center Houston and two observatories. Eclipse chaser John Mason then leads the main event at an exclusive ranch. This eight-day tour begins on 3 April and costs £4399.

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Podcast

Weekly

The team reveal how fungi in soil grow faster when you play them music. You can also get the lowdown on whether the machines really are coming for our jobs. On a related note, there is already a robot avatar that can attend events on your behalf. Plus, why owls may be better at turning their heads than we thought.

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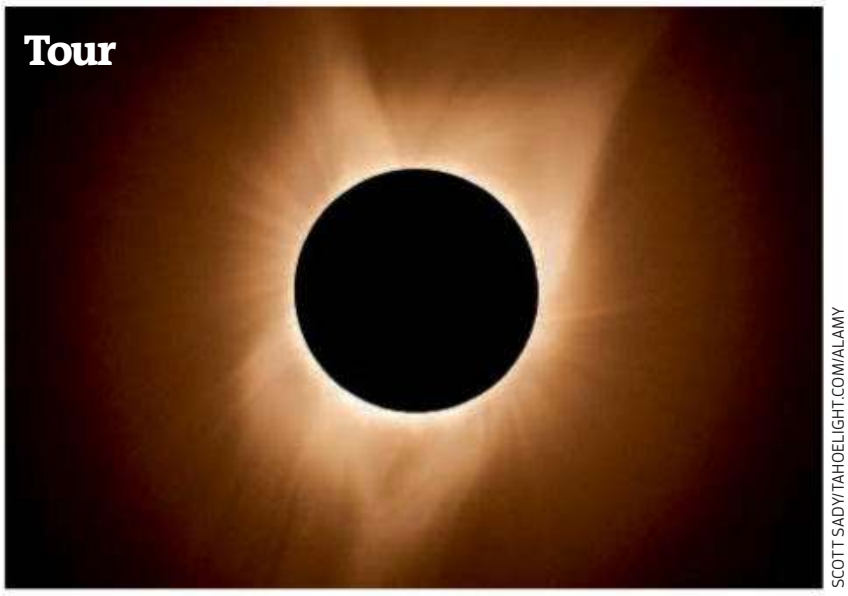

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Eclipse chasers The perfect spot to watch this year's solar eclipse

SARAH GRIGOR/ALAMY

Bohemian waxwings Winter displays like this are slowly declining

Video

What it is like to be a bee

A bird's or bee's view of the world can now be seen through a camera system that captures videos in both visible light and UV to match the way that colours appear to different species. The technology works even when objects are in motion or are seen from different angles. Researchers are using the system to understand how animals use colour in behavioural displays.

youtube.com/newscientist

Newsletter

Wild Wild Life

Penny Sarchet considers why the UK winter is a good time for a taste of bioabundance. Large groups of birds, like Bohemian waxwings, travel from northern Europe to avoid the cold, but these spectacles are becoming less impressive and we may not notice due to something called shifting baseline syndrome.

newscientist.com/wild-wild-life

Podcast

"Owls choose to keep this secret from us. They are not what they seem"

Essential guide

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Gold hydrogen fever

Earth may hold huge deposits of carbon-free fuel, but we can't count on it yet

HYDROGEN is the most abundant element in the universe and yet, for a long time, it wasn't thought to be particularly plentiful in its free form – as a reactive gas – here on Earth. Prospectors drilling for oil and methane sometimes discovered natural hydrogen in their wells, and it was found seeping out in odd places, such as the perpetual flames of Turkey's Mount Chimaera. But most experts assumed that underground accumulations of naturally occurring hydrogen were small and rare.

Not any more. In the past couple of years, new detections of natural hydrogen and a better understanding of how it is generated have raised the prospect that Earth might contain vast stores of what some call "gold hydrogen". Inevitably, that has led to a surge of excitement. The idea is that a ready natural supply of this clean-burning gas could transform our efforts to abandon fossil fuels. One widely cited estimate suggests there may be enough gold hydrogen beneath our feet to meet a lot of our energy demands for centuries.

"There could be enough buried hydrogen to meet a lot of our energy demands for centuries"

A clutch of ambitious start-ups is now engaged in a race to find deposits and figure out how best to extract the gas, as we report in our story on page 32.

But as gold hydrogen fever takes hold, there are grounds for caution. Nearly everything about geologic hydrogen, to give it its proper name, remains uncertain, including exactly where it comes from, how much really exists and, crucially, what accumulations might be feasible to exploit. There would also be challenges regarding storage and transport, and worries over the environmental and social costs of a hydrogen-drilling infrastructure.

To overcome some of the uncertainties, at least one company is proposing to inject water and heat into rocks underground to produce hydrogen, in a process roughly akin to fracking. But that comes with other risks, of course. And for all the hype, hydrogen hunters have yet to make a find of the magnitude we are hoping for.

Until they do, and until we know for sure that hydrogen extraction is scalable, we should see it for what it is: an exciting prospect, but with many unknowns. ▮

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General & media enquiries
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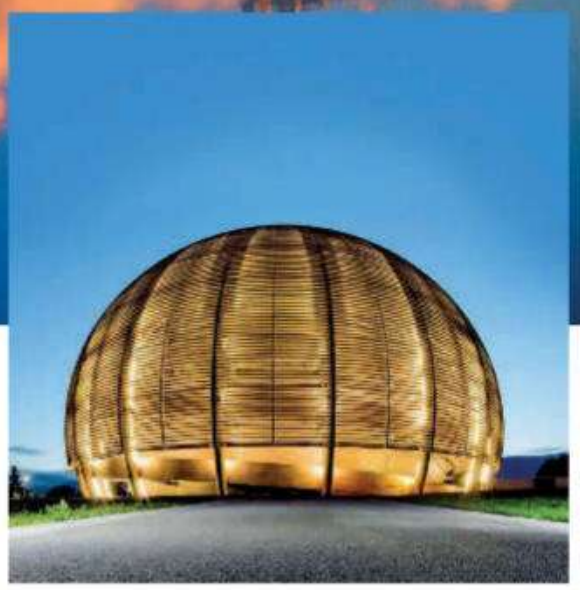


CERN and Mont Blanc: Dark and frozen matter: Switzerland and France

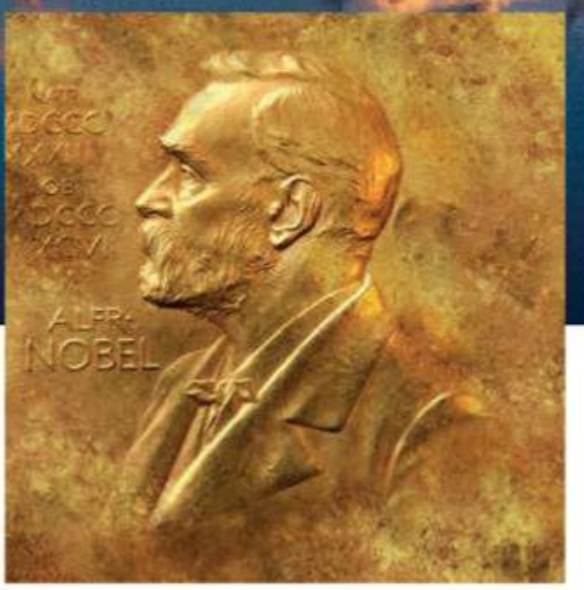
5 May and 8 October 2024 | 6 days

Explore Europe's particle physics centre, CERN, where researchers operate the famous Large Hadron Collider, nestled near the charming lakeside town of Geneva. Discover CERN and Geneva's fascinating histories before heading to Chamonix to explore Mont Blanc and the nearby glacier. During the tour, enjoy private lectures from particle physicist Darren Price, who will also give a personal guided tour of CERN.

Bohr's Copenhagen: Physics past and future: Denmark

3 July 2024 | 6 days

Explore the institutes and sites where Bohr formulated his theories and research, uncovering a rich history of scientific developments not only from Bohr, but from a whole host of Danish Scientists including Tycho Brahe and Ole Rømer. Today, Copenhagen is a bustling city with trendy markets, shops, art, natural spaces, impressive architecture and laid-back people. Experience Copenhagen's scientific heritage as you explore the city and hear from a raft of experts.



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28 September 2024 | 6 days

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Cold connection
Plagues that shook the Roman Empire linked to climate **p11**

Lab-grown food
Engineered cells could slash cost of cultured meat **p12**

Old smokers
Newly discovered ancient stars emit strange clouds **p14**

Cancer check
Smart sticker monitors tumour growth **p15**

REUTERS/MIKE BLAKE

Space flight

An upstanding Endeavour

After about six months of preparation, NASA's space shuttle Endeavour has been lifted – covered in protective shrink-wrap – into place for upright display at the Samuel Oschin Air and Space Center in Los Angeles. The building will be finished around the 37-metre-long shuttle before it is fully unveiled. Endeavour flew 25 times before the shuttle programme ended in 2011.

Virology

New virus-like replicator discovered

Previously unknown replicating agents named "obelisks" have been found in genomic data from stool samples – but we know little about what these entities do, says **Michael Marshall**

A PREVIOUSLY unknown type of replicating agent, far smaller and simpler than a virus, has been found in the human gut. These entities have been called "obelisks" by their discoverers.

The obelisks are a "completely new category", says Beatriz Navarro at the Institute for Sustainable Plant Protection in Bari, Italy, who wasn't involved in the find. She calls them "a very impressive discovery" that "opens thousands of new questions".

They were discovered by a team led by Andrew Fire at Stanford University in California, who shared the 2006 Nobel prize in physiology or medicine. Because the research hasn't yet been peer-reviewed, Fire declined to be interviewed.

The obelisks are most similar to another kind of microscopic infectious agent, called viroids. The more familiar viruses, like the one that causes covid-19, are made up of a piece of genetic material like DNA or RNA, surrounded by a protein shell. In contrast, viroids lack this outer layer: each one is just a circular strand of RNA. They are so small, they were only discovered in the 1970s.

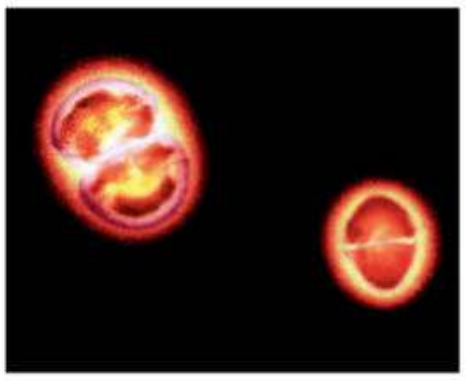
Like a viroid, each obelisk is made solely of RNA, which seems to be circular. But there are crucial differences. The RNA of a viroid doesn't code for any proteins. But the obelisk RNA does. The proteins in question are completely new, bearing no resemblance to any known ones. Fire's team calls them "oblins".

Furthermore, the RNA sequence of the obelisks looks like it would fold up into a tight, rod-like shape, rather than staying as a loose circle. The rod-like shape inspired the "obelisk" name.

Fire and his team discovered the obelisks by searching a library of genomic data collected from human stool samples. They had to create a new search tool to scour the data for unfamiliar RNA sequences.

Once they realised the obelisks were there, they searched more datasets. In total, obelisk RNA was detected in 7 per cent of stool samples and 50 per cent of samples from people's mouths – but these datasets may not be reflective of how common these entities are worldwide (bioRxiv, doi.org/md9d).

"They are not rare," says Navarro. "And if they are there, they have some role."



UK HEALTH SECURITY AGENCY/SPL

***Streptococcus sanguinis* bacteria could be hosting replicators called obelisks**

50%

Obelisk RNA may be in this proportion of people's mouths

7%

Obelisk RNA detected in this proportion of stool samples

Behavioural clues

For now, we know little about what the obelisks do. The discovery is solely based on analysing existing genomic data. The next step, says Navarro, is to perform physical experiments to confirm their rod-like structure and start studying their behaviour.

However, Fire and his team found one more clue to the obelisks' behaviour. They discovered that some laboratory strains of the bacterium *Streptococcus sanguinis* contained obelisk RNA sequences. The implication is that the obelisks are infecting *S. sanguinis*. They may be using its cellular machinery to replicate themselves – as viroids do.

"It is a very impressive discovery that opens thousands of new questions"

S. sanguinis is found in our mouths. It is normally beneficial, being associated with good oral health. However, if it gets into the blood, it can cause inflammation of the heart, or endocarditis.

Navarro wants to know if the obelisks affect the behaviour of *S. sanguinis*. "Is the bacteria with this element more virulent? More pathogenic or less pathogenic?" she asks. "It's an open question."

It may be that, just as some viruses that infect bacteria can be used to treat bacterial infections, obelisks could one day be used in medicine.

The obelisks are the latest in a series of discoveries, often using metagenomics, that are expanding our notions of what viruses, viroids and viroid-like agents can look like. For example, in 2023, a team that included Navarro identified "ambiviruses": viroid-like objects that appear to infect fungi.

Viruses are often said not to be alive, since they can only replicate inside a host, but it is a contentious issue. The same questions apply to viroids – and potentially to obelisks.

In 2022, Navarro and her colleagues suggested that RNA-based entities like viroids could date back to the earliest history of life. Some biologists suspect that the first life was based mostly or solely on RNA. If so, viroids and obelisks could be relics of this "RNA World". ▮

EMMA INNOCENTI/GETTY IMAGES

The newfound replicating agents may live in bacteria in our mouths

Space

What we know about the stars where NASA will hunt for life

Jonathan O'Callaghan

ASTRONOMERS have examined the stars that a new multibillion-dollar space telescope might target, to prepare for one of the most advanced searches for life on other planets. They have found which systems may be better suited to hunt in for potential alien life.

In the 2040s, NASA plans to launch the Habitable Worlds Observatory (HWO). Its big goal is to image about 25 Earth-like planets in the habitable zones of sun-like stars – where water, or even life, could exist. Before construction on the HWO begins, scientists are tackling some of the key hurdles it will face.

One of those is selecting the stars within about 100 light years of Earth that the telescope might target. Caleb Harada at the University of California, Berkeley, and his colleagues have analysed 164 candidate stars to gauge what we know of them. "We're trying to get the ball rolling so we can fill in our knowledge gaps," says Harada. These may become some of the most studied stars in history.

The list of candidates includes Tau Ceti, a sun-like star 12 light years away that is believed to host multiple planets, and 82 G. Eridani, 20 light years away, which is known to have at least three super-Earths, with masses bigger than Earth's but smaller than Neptune's. So far about 47 of the stars have been ranked as "Tier A", the most promising targets for HWO. However, Eric Mamajek at NASA's Jet Propulsion Laboratory in California, who jointly drew up the initial group of 164, says the full list is "very much provisional".

Harada and his team showed that 102 of the stars are binary ones, which may complicate a search for life. HWO will use a tool known as a coronagraph to block out the starlight to try to image planets in orbit, also picking apart the gases in their atmospheres. "If [binaries are] too close together, the unblocked star would swamp the image and you wouldn't be able to see planets," says Bruce Macintosh at the University of California Observatories.

Giant Earth-like exoplanets may host extreme forms of life in hot spring craters

STEVEN HOBBS/STOCKTREK IMAGES/ALAMY

Of the stars, 33 are also known to have debris discs that could make it hard to image planets. "It's an extra source of flux," says Harada. And some of the stars are prone to flaring events. These aren't necessarily deadly to life, considering our sun emits solar flares, but they will need to be studied to make sure they aren't too intense. "These can affect life and habitability," says Harada.

The composition of many of the stars is known, which can directly translate to the composition and habitability of any orbiting planets. "We might want to [focus our search on stars with] the chemical elements that are essential for life, including carbon, nitrogen and phosphorus," says Harada. But not all stars are known in such detail, making them prime targets for follow-up study in future (arXiv, doi.org/md9s).

Any of these stars could be where life is first detected outside our solar system, so telescopes will be trained on them before HWO launches. "People are going to study the heck out of them," says Macintosh. ▮

Animal behaviour

Bees tend wounds, which suggests that they feel pain

BEES have been observed grooming hurt body parts, which may indicate that they feel pain.

Many insects continue to feed and mate when wounded, which had previously led researchers to assume that insects don't feel pain.

"This [grooming] in itself is not direct evidence for pain," says Lars Chittka at Queen Mary University of London. "But it's an important dent in the argument that insects obviously don't feel pain."

A creature might be able to process hurtful stimuli in its brain without necessarily experiencing an unpleasant feeling of pain. However, measuring this is tricky and we can't ask an insect to communicate what it feels.

Instead, Chittka's team looked at whether buff-tailed bumblebees (*Bombus terrestris*) responded to a painful stimulus by grooming the resulting wound. The researchers divided 82 bees into three groups. One group received a touch on one of their antennae with a soldering iron heated to 65°C (149°F), while another group was prodded on an antenna with an unheated iron. The third set wasn't poked at all. In the 2 minutes following the burn, the scorched insects groomed and tended to their antennae more often, and for longer, than the other groups (bioRxiv, doi.org/md9b).

"It's a very strong difference," says Chittka. "No subtlety at all."

The finding is part of a growing body of research indicating that insects may feel emotions. It builds on previous studies suggesting that bumblebees will accept a painful experience only in exchange for a particularly sugary reward and that they might feel enjoyment because they freely engage in play.

"This study provides an important part of the overall picture," says Heather Browning at the University of Southampton, UK.

But Nicholas Humphrey at the London School of Economics says grooming an injury could just be an evolved response to mitigate damage, not a sign of pain. ▮

"It's an important dent in the argument that insects obviously don't feel pain"

Sofia Quaglia

Artificial intelligence

AI mimics sleep to learn better

Making models rehash learned data in a sleep-like state boosts performance

Matthew Sparkes

BUILDING artificial intelligences that sleep and dream can lead to more reliable models, according to researchers who aim to replicate the behaviour of the human brain.

Concetto Spampinato and his colleagues at the University of Catania, Italy, were looking for ways to avoid a phenomenon known as "catastrophic forgetting", where an AI model trained to do a new task loses the ability to carry out jobs it previously aced. For instance, a model trained to identify animals could learn to spot different fish species, but then might lose its proficiency at recognising birds.

They developed a method of training AI called wake-sleep consolidated learning (WSCL), which mimics the way that, when we are asleep, our brains shuffle short-term memories of things we learned during the day.

Models using WSCL are trained as usual on a set of data for the "awake" phase. But they are also programmed to have periods of "sleep", where they parse a sample of awake data and a highlight reel from earlier lessons.

"The human brain should not be regarded as the ultimate architecture for intelligence"

An animal identification model recently trained on images of marine life, for example, could be shown snapshots of fish during a rest period, but also a smattering of birds, lions and elephants from older lessons. Spampinato says this is akin to humans mulling over memories while sleeping, spotting connections and patterns.

WSCL also has a period of "dreaming", which involves novel data made from mashing together previous concepts. For instance, the animal model might be fed images showing combinations of lions crossed with elephants. Spampinato says this helps to merge previous paths of digital "neurons", freeing up space for other concepts in the future. It also primes unused neurons with patterns that will help them pick up new lessons more easily.

"You might combine panda, giraffe and leopard, so you'll create this very strange mythological figure, and that will force the model to learn more complex patterns that maybe in the future can be reused," says Spampinato.

The researchers tested three AI models using a traditional training method, followed by WSCL training. Then they compared performance using standard benchmarks for image identification. The sleep-trained models were 2 to 12 per cent more likely to correctly identify the contents of an image. They also measured an increase in the WSCL system's "forward transfer", a metric indicating how much old knowledge a model uses to learn a new task (arXiv, doi.org/md9c).

Despite these promising results, Andrew Rogoyski at the University of Surrey, UK, says using the human brain as a blueprint isn't necessarily the best way to boost AI performance. "The human brain should not be regarded as the ultimate architecture for intelligence," he says. He suggests mimicking dolphins, which can "sleep" with one part of the brain while another part remains alert. After all, an AI that requires hours of sleep isn't ideal for commercial applications. ▮

Space exploration

SLIM moon lander regains power after botched landing

JAXA

Japan's lunar lander was photographed upside down by one of its rovers

JAPAN'S moon lander resumed contact with Earth, nine days after it entered a power-saving hibernation mode. It had landed incorrectly and lost the ability to generate energy.

The Smart Lander for Investigating Moon (SLIM) touched down on 19 January, making Japan only the fifth country to have successfully landed a lunar spacecraft. SLIM managed to end up within 55 metres of its target location, using a new and precise landing system, but one of its thrusters failed during its descent.

The Japan Aerospace Exploration Agency (JAXA) received information that the craft had landed upside down, with its solar panels facing the wrong way to generate electricity.

For just over 2 hours, SLIM managed to collect and send back data and images to Earth using its backup battery power. However, that was only designed to last for a few hours, so JAXA engineers put the spacecraft into hibernation when it reached 12 per cent charge, in the hope that the solar panels might start working again when the sun moved across the sky.

JAXA finally reconnected with SLIM on 28 January, after the sun shone from the west in the lunar afternoon, striking SLIM's solar panels. This enabled the lander – still upside down – to continue its scientific operations, and it began to analyse the rock composition near its landing spot.

Even with the extra power, SLIM has limited time to do its work. It was still operational as *New Scientist* went to press, but the lunar night began on 1 February and will last 14 Earth days. JAXA has previously said the lander isn't designed to survive the dark, freezing conditions this will bring.

However, two small autonomous rovers that made the journey with SLIM were released on arrival on the surface and have already sent back pictures. These vehicles will keep exploring and sending back data even if the lander itself fails. ▮

Alex Wilkins

Technology

Patch with 'octopus suckers' helps drugs penetrate the skin

Karmela Padavic-Callaghan

A MATERIAL covered with octopus-like suckers could provide a needle-free way to deliver drugs through the skin.

JIHYUN LEE ET AL. (2024)

This adhesive patch can get drugs into the skin by mimicking octopus tentacles

Jihyun Lee at Sungkyunkwan University in South Korea and her colleagues have designed a patch made of stretchy, transparent rubber a few centimetres in length. One side is smooth and the other is coated with suction cups, each about 3 millimetres across, inspired by the suckers on octopus tentacles.

The researchers reasoned the suckers could clamp onto skin, deforming it and temporarily reducing its ability to act as a physical barrier. This would help medication soak through the skin.

To test the idea, they attached the patch to samples of pig skin, human skin and a type of artificial skin. In each case, the patch left skin temporarily more permeable to substances such as vitamin A1 and the antibiotic ramoplanin.

The compounds penetrated up to two-fifths of the way through the skin, reaching the topmost layer of the epidermis – the stratum corneum – which has low permeability. They were also absorbed for about 30 minutes after the patch was removed (*ACS Nano*, doi.org/md89).

It is important to find ways to deliver drugs without needles, to make it cheaper and easier for people to self-administer medication, says Stuart Jones at King's College London.

Another use might be for cosmetic products, says Lee. ▮

Environment

Plagues that shook the Roman Empire linked to cooler climate

Alec Luhn

THREE pandemics in the Roman Empire coincided with abnormally cold and dry periods, suggesting that natural changes in climate may have contributed to Rome's decline.

Kyle Harper at the University of Oklahoma and his colleagues reconstructed the climate of southern Italy between 200 BC and AD 600 by analysing the remains of plankton in a sediment core from the Adriatic Sea.

The Roman state flourished and reached its greatest extent during the three centuries of relatively warm and wet weather beginning in 200 BC in what is now Italy. But the study found that this "Roman climate optimum" gave way around AD 130 to an era that was up to 3°C (5.4°F) colder and with more frequent droughts.

Especially frigid years corresponded with the Antonine Plague that occurred in AD 165-180, which shook the empire and possibly killed Emperor Lucius Verus.

Another plunge in temperatures came during the Plague of Cyprian in AD 251-266, when the empire

3°C

Climate cooling that coincided with Roman Empire plagues

was splintering into three states ruled by warring generals and a rebel queen.

Then, after the fall of the Western Roman Empire in 476, one of the coldest periods in the past 2000 years heralded a wave of pandemics starting with the Plague of Justinian in the 540s.

This could have contributed to the loss of much of Italy, the Balkans and the Middle East

THE WALTERS ART MUSEUM/SCIENCE PHOTO LIBRARY

A 7th-century outbreak of plague in Italy, painted by Josse Lieferinxe

from the territory of the Eastern Roman Empire.

"The Roman Empire rises and falls and rises and falls," says Harper. "There's a series of episodes of very extreme crises in some cases. And I think the case is now overwhelmingly clear that both climate change and pandemic disease had a role in many of those episodes."

While there are signs of these cold spells in tree rings from the northern Alps, the sediment core in this study, which was taken at the end point of a current running along the entire eastern coast of Italy, offers the first clear evidence of them in the Roman heartland.

Warm-water plankton species declined in the sediment layers from these years, says Karin Zonneveld at the University of Bremen in Germany, co-author of the study. The team also saw a decrease in species that depend on nutrients deposited by rivers, indicating aridity.

Cooler, drier conditions may have disrupted harvests, weakening the immune systems of Roman citizens and encouraging the spread of disease through migration and conflict (*Science Advances*, doi.org/md87).

Before the Plague of Justinian, which was caused by the same flea-borne bacterium as the 14th-century Black Death, three massive volcanic eruptions dimmed the sun and launched the "Late Antique Little Ice Age". Historical accounts from this time recorded crop failures.

"The sun gave forth its light without brightness, like the moon," wrote the scholar Procopius in 536. "Men were free neither from war nor pestilence nor any other thing that brings death."

Climate trigger?

While this new sediment record advances our understanding of Roman Italy, we don't know enough about the rest of the empire to say whether climate change triggered or amplified the plagues, says Timothy Newfield at Georgetown University in Washington DC. He has argued that the effects of the Plague of Justinian have been exaggerated.

"Whether these three Roman pandemics specifically brought down Rome is, in my opinion, hard to argue," he says. "No one variable or two variables can be held accountable."

But Harper says the study should raise questions about climate change in the Roman era, as well as our own: "It gives you perspective to understand that two to three degrees [Celsius] of change is absolutely enormous and puts tremendous strain on human societies." ▮

Mind

Playing piano triggers changes in the brain

Moheb Costandi

LEARNING to play the piano causes complex shifts in brain activity that vary over time.

Initially, areas associated with memory, integrating sensory information and processing movement became highly activated as people learned to play the instrument, but this lessened as their ability improved.

26

Length in weeks of the study in which people learned piano

Previous studies have looked into the reorganisation of people's brain activity while they are playing an instrument, but these have generally been short and based on only one scan.

To learn more about this process, Alicja Olszewska at the Nencki Institute of Experimental Biology in Poland and her colleagues studied 24 people as they learned to play the piano over 26 weeks.

The process involved a teacher showing the participants basic techniques, as well as coaching them through eight increasingly complex pieces of music during 13 classes, each lasting 45 minutes. The volunteers were also encouraged to practise at home for 4 hours a week.

After one, six, 13 and 26 weeks of training, the researchers used functional magnetic resonance imaging to scan the participants' brains as they attempted to play the increasingly tricky pieces.

The scans showed that playing the piano activates multiple areas across the brain, including the auditory cortices that are involved in processing sounds and the motor cortices involved in the planning and making of movements.

Over the 26 weeks, activity changed little in the auditory cortices, but it generally decreased in the motor cortices. A reduction in brain activity represents its optimisation, which would be expected as the participants' piano-playing skills progressed, says Olszewska.

The scans revealed that learning to play the instrument initially activates other areas of the brain, including the cerebellum, which coordinates movement, and parts of the parietal cortex, which integrate different types of sensory information.

Olszewska and her team also found increased activation in the hippocampus, involved in memory, and the basal ganglia, a set of deep brain structures involved in initiating and controlling voluntary movements (bioRxiv, doi.org/md62).

Activity in these areas similarly decreased as the participants' training progressed. This suggests that their underlying neural processes became increasingly optimised as they became more musically proficient, says Olszewska. ▮

Playing the piano activates multiple areas across the brain

TIM RING/ALAMY

Bioengineering

Engineered cells could slash cost of cultured meat

Chen Ly

COW muscle cells have been engineered to multiply themselves in a lab. The researchers behind the work are optimistic that this could make it cheaper to grow meat in labs, but they say it is still early days.

Lab-grown, or cultivated, meat can be produced from animal cells. Approved for sale in countries including the US and the Netherlands, it has been touted as a more ethical and sustainable substitute for conventional meat because it avoids the slaughter of animals and uses fewer resources, such as water.

But current, small-scale methods of producing lab-grown meat are still extremely energy intensive and expensive. Some estimates say the carbon footprint of cultivated meat is worse for the climate than beef.

To grow cells outside an animal, they must be cultivated in a cell culture medium, a mixture of nutrients and growth factors. The latter latch onto receptors on the surface of animal cells and tell them to grow and differentiate, making growth factors a crucial part of the mixture, according to Andrew Stout at Tufts University in Massachusetts.

Producing growth factors makes up about 90 per cent of the cost of lab-grown meat production, so Stout and his colleagues wanted to come up with an alternative approach.

They first built small DNA molecules called plasmids that contained genes with instructions for cells to produce growth factors for fibroblasts, cells that help to form connective tissues.

The researchers then inserted these plasmids into cows' muscle cells, finding that they differentiated into skeletal muscle cells, common components of steaks and beef burgers, that grew and multiplied (*Cell Reports Sustainability*, doi.org/gtfzxs).

Cells as allies

Although Stout and his colleagues only experimented with cow cells, they think the technique will also work on cells from other animals, such as chickens and pigs. They hope these engineered cells could one day aid in expanding the scale and lowering the cost of cultivating lab-grown meat.

"Give a cell a fibroblast growth factor and it'll grow for a day, but teach a cell to produce its own fibroblast growth factor and it'll grow forever," says Stout. "This is just a proof of concept, but it's really exciting to think about how cells can be our allies in this endeavour and we can engineer them to help us."

"There is still a long way to go until lab-grown meat becomes a commodity, but every day we are getting a step closer to it," says Eirini Theodosiou at Aston University in Birmingham, UK.

"Every day we are getting closer to lab-grown meat becoming a commodity"

Issues that still need to be overcome include the team's cultivated meat growing slower than with conventional approaches, says Theodosiou.

In addition, foods that contain genetically modified material, such as these plasmids, are only legal in some countries and there is still a widespread reluctance to eat them, she says. ▮

Cosmology

Smash-ups may explain light leaks

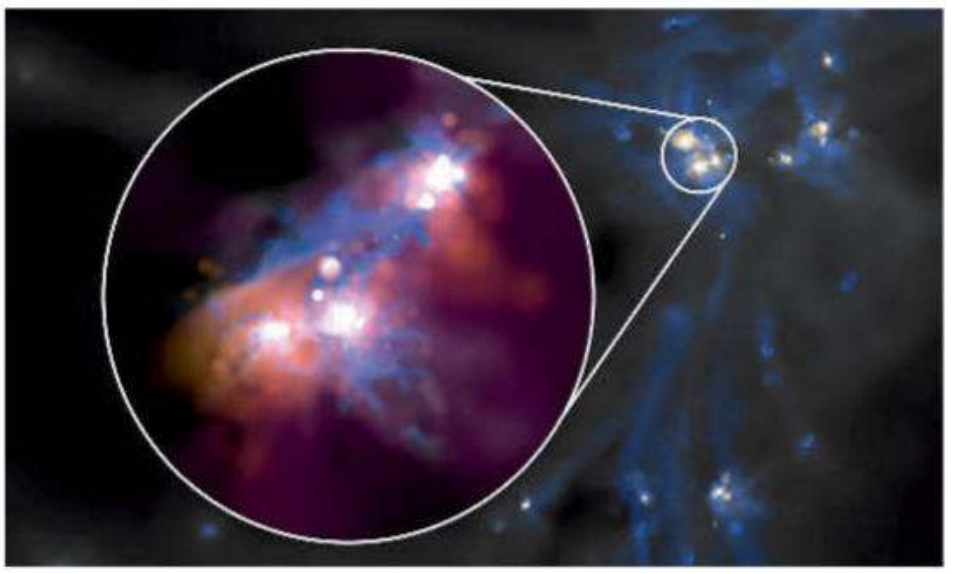
We may now know why strange light emissions from the early universe have been reaching us

Leah Crane

OBSERVATIONS from the James Webb Space Telescope (JWST) have revealed dim galaxies smashing together, which could tell us why we have seen strange glints of light from early in the cosmos.

For a long period of the universe's history, ending about 1 billion years after the big bang, space was full of a pristine gas that should have blocked out the copious light emitted by hydrogen atoms. But researchers have seen twinkles of hydrogen shining from many galaxies in the early universe. This is a type of light known as Lyman-alpha emission.

How this light escaped the shroud of gas has baffled astronomers, but Callum Witten at the University of Cambridge and his colleagues have found a potential solution. They examined JWST images of nine distant galaxies, all putting out Lyman-alpha emission, and found that all of them had at least one smaller galaxy right next to them. These secondary galaxies were too faint to be seen with other telescopes, and all seem to be merging with their brighter partners.



S. MARTIN-ALVAREZ

Merging galaxies from the early universe imaged by the James Webb Space Telescope

Merging galaxies create bursts of star formation and light, including Lyman-alpha emission. They also generate powerful winds that could blow away the galaxies' cosmic gas, allowing the light to escape. Those winds and the energy from the star formation could also strip gas atoms of their electrons, which would stop the gas from absorbing light and render it transparent.

"We were aware there was a chance that we were missing fainter galaxies, but we weren't aware that there would be so many so close to these brighter galaxies," says Witten. "We weren't aware that they were helping allow this emission to get out."

The researchers ran a series of simulations to test their hypothesis, and they found that the interactions between the galaxies did indeed create odd channels through the gas, allowing the hydrogen emission to leak out in such a way that our telescopes could spot it (*Nature Astronomy*, doi.org/gtd4v6).

"We had a sort of biased view of these very early galaxies before and it failed to account for the chaotic process of them merging," says Witten. "This emission we thought shouldn't exist, this has explained that."

There are other possible explanations, including turbulence from active black holes at the centres of these galaxies, but it seems that galactic mergers must play a role, says Witten. However, with a sample of only nine galaxies, we can't be sure it is the only answer.

"To really prove this hypothesis, we'll have to see how this holds up when we detect dozens more, if not a few hundred, in the coming years," says Aayush Saxena at the University of Oxford, who wasn't involved in this work. "If we continue to find these merging galaxies, then that mystery will really be solved."

Witten and his colleagues are now waiting for JWST data on more Lyman-alpha emitters to become publicly available. ▮

Technology

Layer of graphene could help protect historical statues

GRAPHENE could be a powerful tool for preserving paintings, statues and historical buildings.

Often called a wonder material, graphene consists of a single layer of carbon atoms and is resistant to heat, acids and physical damage. It also absorbs only about 2 per cent of visible light, making it mostly transparent and a good candidate for shielding artwork. Mauro Moglianetti at the Italian Institute of Technology and his colleagues have reviewed dozens of experiments using graphene in this way.

"I was astonished by the number of possibilities," he says.

In one experiment, Costas Galiotis at the University of Patras in Greece and his colleagues transferred metre-sized sheets of graphene onto real paintings to shield them against the degrading effects of UV light, oxygen and moisture. Unlike other anti-fading varnishes and coatings, the graphene membranes are easy to remove, says Galiotis.

Graphene or graphene-derived compounds, such as graphene oxide, have also been added to mortars used for restoring historical buildings and statues.

J BANAGAN/LONELY PLANET/GETTY

A coating of graphene could protect the Leshan Giant Buddha statue in China

Yulan Hu at Zhejiang University in China and her colleagues tested a spreadable mixture made from particles of copper and oxygen plus graphene oxide on red sandstone, which the Leshan Giant Buddha in Sichuan province, China, is carved from. They then brushed it on samples covered in moss to mimic the damaging vegetation growing on the statue. After 30 days, the moss mostly dried out and stopped growing (*Advanced Functional Materials*, doi.org/md7q).

Mortars that contain graphene could be used on statues and buildings soon, says team member Camilla Coletti, also at the Italian Institute of Technology. "There are start-ups that could make them already." ▮

Karmela Padavic-Callaghan

Physics

Time to rethink thermodynamics?

Heating and cooling seem to be fundamentally different processes, not mirror images

Alex Wilkins

HEATING something up will always be quicker than cooling it down on a microscopic scale, according to a proposed new principle of thermodynamics. The two processes, long thought of as two sides of the same coin by physicists, seem actually to be fundamentally different.

Physicists have long argued over a definition of temperature. A school textbook might say it is a measure of the degree to which atoms jiggle around in a system. But thermodynamics, the study of the relationship between heat and other forms of energy, describes temperature as a measure of how many different arrangements of values, such as speed or energy, all the atoms in a system can have. These arrangements are called microstates.

Based on this, thermodynamics says heating and cooling are essentially mirror images of each other. However, this assumes that temperature changes happen slowly or over small increments.

UZANNE KREITER/THE BOSTON GLOBE VIA GETTY IMAGES

The laws of thermodynamics explain much of heating and cooling, but not everything

When systems heat up or cool down over large intervals, the physics is less understood and results can be counterintuitive. For example, hot water freezes faster than cold, a phenomenon called the Mpemba effect.

Now, Aljaz Godec at the Max Planck Institute for Multidisciplinary Sciences in Göttingen, Germany, and his colleagues have found that a microscopic sphere of silica that has its temperature rapidly oscillated appears to heat up faster than it cools.

"So far, we know that this is true because we have shown it, but I don't think we can claim that we understand why," says Godec.

The researchers placed the tiny sphere in water and trapped it in place using a laser. They then applied an electric field to heat or cool it and measured how much it jiggled and moved, repeating this tens of thousands of times.

Measuring a single particle like this is equivalent to measuring a single microstate, which is impossible to do for a material consisting of many particles due to the vast number of possible configurations. But by making many measurements for a single particle, Godec and his colleagues could map out the number of possible microstates it can take.

The researchers then measured how many microstates the particle would have to go through when transitioning between two temperatures. They found it had to travel through fewer possible microstates when heating up as opposed to when cooling, which translated to a faster heating speed (*Nature Physics*, doi.org/gtdzsm).

"The faster heating speed could be considered an extra law of thermodynamics"

The effect could be considered an extra law of thermodynamics, says Janet Anders at the University of Exeter, UK. It expands on the second law, which says hot things cool unless you stop them. "The second law doesn't say anything about speed; it says something about possibility," she says. "This second-and-a-half law, as I'm calling it, says you can do all these things, but some of them will take a lot longer than the inverse." ▮

Space

Newly discovered smoking stars emit huge strange clouds

ASTRONOMERS have discovered stars that appear to be blowing out plumes of smoke. These "old smokers" challenge our ideas of what happens at the end of giant stars' lives.

Generally, when red giant stars grow old, they begin to pulsate. They become brighter, dimmer, brighter again and so on, while simultaneously throwing off their outer layers. These pulsating stars are called Mira variables, and it is thought that the pulses are caused by waves of plasma travelling within the stars that help them shed material into space.

When Philip Lucas at the University of Hertfordshire in the UK and his colleagues peered towards the centre of our galaxy using the Visible and Infrared Survey Telescope for Astronomy in Chile, they saw many Mira variables. But they also spotted something else: "These old red giants not doing any pulsating – they're just sitting there as normal and then suddenly dimming for six months to several years," says Lucas. "This is almost completely unheard of."

Further observations revealed that the stars seem to be emitting huge plumes of dusty smoke that prevent their starlight reaching us.

PHILIP LUCAS/UH

Artist's impression of a red giant star throwing out a cloud of smoke and dust

The smoke takes months to years to dissipate, offering an explanation for the prolonged dimming. This may be a new way for giant stars to end their lives, but it is unclear how or why it is happening (*Monthly Notices of the Royal Astronomical Society*, doi.org/gtfw92).

The enormity of these stars gives them a powerful gravitational field that makes it difficult for them to blow any of their material away. The fact that they aren't pulsating makes it even harder to explain the plumes of smoke.

Lucas suggests that it may be connected to the high concentration of relatively heavy elements near the galactic centre, where most of these old smokers are located. That could make it easier for grains of dust to form and then float away as smoke. "It's quite possible that it's not that, but it's the only thing that's really weird about that region that could be connected," he says. ▮

Leah Crane

Technology

Smart sticker checks tumour growth and shows you in an app

Karmela Padavic-Callaghan

A STRETCHY sticker that clings to skin can monitor the size of some tumours and send that information to an app. The set-up could lead to real-time continuous tracking of how well certain cancers respond to treatment.

Normally, if someone has a tumour, they must go to regular medical check-ups to monitor how treatment is progressing. Hsing-Wen Sung at National Tsing Hua University in Taiwan and his colleagues wanted to develop a device capable of providing some of that information at home.

Specifically, they focused on measuring the size of tumours that exist just under the skin. They built a wearable device – Sung describes it as a "smart, flexible sticker" – out of soft and stretchy plastic, which can cling to the skin and conform to the shape of the tumour underneath it.

The plastic was infused with spindle-shaped particles, each about 100 nanometres long, made from oxygen and the metal hafnium. As the tumour grew, the sticker shifted to accommodate its new size, changing the arrangement of nanoparticles and thus the material's electrical properties (*ACS Nano*, doi.org/gtfwpt).

The researchers tested the device on mice and found the electrical changes could be used to accurately track the development of tumours roughly the size of a grain of rice over the course of seven days.

Parag Mallick at Stanford University in California says devices like this would allow doctors and patients to more quickly determine whether a treatment is effective and react to changes in a tumour's condition. However, because it rests atop the skin, the device wouldn't work for tumours deeper inside the body. This means it will require a redesign to become universally useful, says Mallick. ▮

Animal behaviour

Orangutan calls have complex structure like human language

Michael Marshall

ORANGUTAN calls have a sophisticated structure that was thought to be unique to human language. Short sequences are nested inside longer sequences, much as we assemble long sentences from shorter phrases.

There is no evidence that any complex meanings are encoded in the orangutans' intricate calls. But the fact that the apes can do it means the calls may be a distant precursor to language.

Adriano Lameira at the University of Warwick in the UK, and his colleagues recorded long calls made by large, sexually mature, wild male Bornean orangutans (*Pongo pygmaeus*) in Indonesian Borneo. "They are advertisement calls" to attract females and deter competitor males, says Lameira. "They take the form of 'ooo ooo ooo'."

Lameira wanted to understand the rhythm of the calls. But this proved tricky. "We were having difficulties", he says, because the tempo varied dramatically during each long call: fast bursts of short "ooo" sounds were mixed with longer, slower "ooo" sounds.

Orangutans call to each other for many reasons

GERRY ELLIS/MINDEN/NATUREPL.COM

Closer analysis revealed that the middle of each long call had a regular tempo of long "ooo" sounds, but the beginning and end had bursts of shorter "ooo" sounds, with a range of tempos and acoustic features.

Crucially, the shorter sequences were nested inside longer sequences. This resembles a feature of human language called recursion. We can create complex sentences, for example, by nesting an extra phrase in the middle of a sentence, as with: "The dog, which chased the cat, was barking". The orangutans' long calls had a similar recursive structure (*eLife*, doi.org/md6d).

Previously, researchers have failed to find evidence of recursion in the calls of apes or other non-human animals. The closest anyone has come is training them to recognise recursion – but this isn't the same as observing wild animals actually making such calls. Recursion seemed unique to us.

Lameira says previous searches for recursive calls were unsuccessful because they asked too much of their animal subjects. Humans use recursion to create new and complex meanings, and researchers had looked for animals that do the same. But they seem not to.

His team's analysis didn't look at the meaning of the calls at all. "It was a pure structural analysis," he says.

"It's quite ingenious," says Elodie Briefer at the University of Copenhagen in Denmark. She says the orangutan calls do seem to have a form of recursion, without necessarily having any meaning. Lameira emphasises that there is no evidence the orangutans are encoding deeper meanings in their long calls.

"It would be very logical in terms of evolution that we find these language precursors"

It may be that the recursive complexity is simply a form of showing off similar to birdsong, which can be incredibly complicated without usually meaning anything subtler than "please mate with me".

We should look for similar recursion in other animals, says Briefer. "It would be very logical in terms of evolution that we find these precursors. The opposite would be more strange, that we don't find anything like that in animals, and it only appeared in humans."

Some animals can express complex ideas in other ways: Japanese great tits can string a few sounds together in sequence to create meaning, for example. Such species have rules governing the order they make the sounds, like syntax in human language, but they don't use recursion to generate meaning. ▮

Palaeontology

Exquisite fossils reveal cannibalism

Three fossils of fish from the dinosaur era have members of the same species in their guts

Michael Marshall

SAMUEL L. A. COOPER (2023)

JUVENILE fish sometimes cannibalised their younger fellows during the dinosaur era. They may have done so when food was scarce.

Samuel Cooper at the State Museum of Natural History Stuttgart in Germany studies an extinct group of ray-finned fish called the Pachycormiformes, which lived during the Jurassic Period. "They became extinct right at the end of the Cretaceous, along with the dinosaurs," he says.

At London's Natural History Museum, Cooper found three fossils of a species called *Pachycormus macropterus* that had smaller members of the same species in their guts (one is pictured here).

Other than cannibalism, the only possible interpretation is that *P. macropterus* gave birth to live young, in which case the internalised fish are fetuses. However, Cooper says this probably isn't the explanation. One of the specimens also had the remains of another, unrelated fish in its guts, and, in any case, all three specimens are juveniles (*Journal of Vertebrate Paleontology*, doi.org/mdn5).

"The great thing about gut contents is a lot of the ambiguity is gone. It's definitely cannibalism," says Stephanie Drumheller at the University of Tennessee, Knoxville.

The *P. macropterus* specimens all came from a quarry near Curcy in north-west France. Cooper says it is significant that Curcy is the only site where *P. macropterus* has been observed engaging in cannibalism. "This is a very abundant fossil fish from the Jurassic," he says. That implies cannibalism wasn't their normal behaviour.

The fossils from the site are mostly juveniles, which suggests it was a nursery area. Many fish leave their young in these shallow regions where they are safer from big predators. Cooper suggests that prey was scarce, so the older ones resorted to eating the younger ones. "It's kind of like teenagers eating babies," he says. ▮

Technology

Robot avatar lets people feel things remotely

A HUMANOID robot can relay video and touch sensations to a person wearing a haptic feedback suit and a virtual reality (VR) headset hundreds of kilometres away, offering a way for people to attend events without travelling.

The iCub 3 is a 52-kilogram, 125-centimetre-tall robot with 54 points of articulation across its aluminium alloy and plastic body. Its head contains two cameras where a human's eyes would be and an internet-connected computer where the brain would go.

Along with the cameras, sensors covering its body send data to the robot's "brain". These sensations are then replicated on a suit and VR headset worn by a remote human operator.

When the person operating iCub 3 reacts to what they see and feel, sensors on the suit pick up the movements and the robot matches them.

"The key is to translate every signal and bit of numeric data that can be sent through the network," says Stefano Dafarra at the Italian Institute of Technology, who was part of the iCub 3 team.

There can be a small delay of up to 100 milliseconds to capture and transmit the visual footage, but the operator can mitigate this by moving slightly more slowly than normal (*Science Robotics*, doi.org/gtftdb).

The team has demonstrated the robot in Italy at the Venice Biennale, where it attended an exhibition while its operator stood 290 kilometres away in Genoa.

Dafarra hopes people will use the iCub 3 to attend events remotely, reducing the need to travel. But at present, a fall could be hugely damaging to the robot, and it is uncertain whether it could stand up again on its own, he says.

ISTITUTO ITALIANO DI TECNOLOGIA

iCub 3 is a humanoid avatar that people can embody remotely

"iCub 3 is an interesting robot and offers clear advantages from the previous iteration," says Jonathan Aitken at the University of Sheffield, UK, whose laboratory owns a prior version of the robot.

However, Aitken is disappointed that Dafarra's team wasn't clear in its research about the data transmission requirements of the new version of the robot. "It would be good to know just how much data was required and what the upper and lower bounds were," he says. ▮

Chris Stokel-Walker

Environment

Groundwater levels are dropping fast all over the globe

James Dinneen

IN MANY parts of the world, groundwater levels are declining at concerning rates, which threatens an essential supply of water for people, agriculture and ecosystems.

For years, satellites have recorded rapid declines in groundwater, from California's Central Valley to northern India. But such gravity-based measurements can't capture changes at a more local scale.

To get a clearer picture, Scott Jasechko at the University of California, Santa Barbara, and his colleagues analysed groundwater levels in more than 170,000 wells. The researchers focused on wells for which they had at least eight years of data since 2000. These sites represented nearly 1700 systems of aquifers, or groundwater reservoirs, around the world.

More than a third of the aquifers saw water levels decline by more than 0.1 metres per year, on average, since 2000. Just over 10 per cent saw rapid declines of more than 0.5 metres per year. And a few saw declines of more than 1 metre per year (*Nature*, doi.org/gtftbt).

Jasechko says wells are running dry in many aquifers, and millions of other shallow wells are at risk.

Graham Fogg at the University of California, Davis, says groundwater decline can create issues before aquifers are empty. It can mean salt contaminates the water, cause land to sink and even dry out wetlands.

The researchers also found the rate of decline since 2000 had increased in about a third of the aquifers compared with the rate over the previous two decades.

Data patterns point to below-average rainfall and farm irrigation as the main culprits.

Groundwater loss isn't inevitable, says Jasechko. In about half of the aquifers, declines have slowed or reversed. That suggests efforts to stem depletion, such as hiking the cost of extracting water, can work. ▮

Women's health

US states had 65,000 rape-related pregnancies after banning abortion

Grace Wade

SINCE the US Supreme Court overturned the right to an abortion, estimates suggest that there have been tens of thousands of pregnancies as a result of rape in states with near-total abortion bans. Very few, if any, of those pregnancies were ended by a legal in-state abortion, even if states had exceptions for rape.

The right to an abortion was protected in the US for nearly 50 years under the landmark 1973 Roe v Wade legal ruling. But in June 2022, the country's Supreme Court repealed this decision, allowing states to decide whether abortion is legal. Since then, 14 states have outlawed nearly all abortions.

To understand how this affects survivors of rape, Samuel Dickman at the reproductive health non-profit Planned Parenthood of Montana and his colleagues estimated how many rape-related pregnancies happened in these states between July 2022 and January 2024.

The researchers first looked at the most recent data from the US Centers for Disease Control and Prevention on rape incidents, which was collected between 2016 and 2017. From that, they could approximate the proportion of rapes that resulted in pregnancy nationwide each year.

14

Number of US states that have outlawed nearly all abortions

They then used data from law enforcement to estimate the number of rape-related pregnancies in each state since abortion bans were enacted. The result suggests that almost 65,000 people became pregnant as a result of rape in the 14 states.

More than 90 per cent of those individuals lived in states where there weren't exceptions that allow for an abortion in the case of rape (*JAMA Internal Medicine*, doi.org/mdpm).

Even in states with exceptions, fewer than a dozen legal abortions are being performed each month. One reason for this is that these states no longer have abortion providers, says Dickman. Plus, "most of the states with rape exceptions require some amount of reporting to law enforcement", he says. "That's a decision many survivors of rape choose not to do."

Most sexual assaults go unreported due to stigma and fear of retaliation. That is also why these findings are most likely to be an underestimate, says Dickman.

Previous research shows that people denied abortion are more likely to stay with abusive partners, live in poverty and have poorer mental and physical health. These consequences may be especially pronounced for survivors of sexual assault. "The psychological impact of that is incalculable," says Dickman. ▮

A protest against the repeal of Roe v Wade in Washington DC in 2022

TASOS KATOPODIS/GETTY IMAGES

Health

Retinal images could predict future risk of heart or lung disease

Timmy Broderick

WANT to know more about your risk of having heart or lung problems? The thickness of your eyes' retinas may hold important clues.

Researchers have previously established links between the thickness of the retina and whole-body health, but a new study provides more detail about its potential for predicting future risks.

Now, using data from 44,828 participants, Nazlee Zebardast at Harvard Medical School and her colleagues have found that having thinner retinas is correlated with an increased risk of ocular, neurological and cardiovascular conditions. This is also the first study to find that a thinner retina increases a person's risk of developing a lung condition like bronchitis or emphysema later in life (*Science Translational Medicine*, doi.org/gtftc8).

The data came from the UK Biobank, which contains anonymous details about the health and genetics of about half a million people in the UK. The retinal images included in the data were captured using a non-invasive procedure called optical coherence tomography. Ophthalmologists routinely use this technique to determine someone's risk for various eye conditions, including macular degeneration and glaucoma. The procedure captures information about the retina – which is usually 0.5 millimetres thick – and its internal layers.

Zebardast hopes the finding will eventually expand how optical coherence tomography is used. Beyond simply giving details about the eyes, she would like to see it become a tool for providing information about the whole body.

"We have patients coming to our eye clinic all the time," she says. "Wouldn't it be great if we could tell from someone's retinal image, 'you look like you might have a high risk of sleep apnoea', or 'you might have a high risk of developing diabetes'?"

While exciting, this technology is still "a long way off" from immediate clinical application, says Anthony Khawaja at University College London. Researchers are still unsure why retinal biology might correspond to systemic health, or what kind of mechanism might be driving the associations seen in this study and others. Zebardast and her colleagues also point out that a lack of genetic diversity within the UK Biobank sample limits the universal applicability of the findings: 94 per cent of the people who contributed their data to the database have white European ancestry.

Still, Zebardast is optimistic. If studies that track people for years confirm that a thinner or thicker retina does actually correspond to an elevated risk of developing certain conditions, then retinal imaging could emerge as a useful and non-invasive method for routine health screening. ▮

Environment

Toxic mud can be used to make greener steel

THE huge reservoirs of hazardous red mud that are produced as part of refining aluminium could be used to make greener steel.

There are roughly 4 billion tonnes of red mud stored around the world, which is an environmental hazard that can lead to deadly accidents.

Steel production, too, is bad for the environment: making a tonne of it generates nearly 2 tonnes of carbon dioxide. This happens because most steel production involves burning fossil fuels to react carbon with the oxygen in iron ore, yielding iron but also CO_2.

Isnaldi Souza Filho at the Max Planck Institute for Iron Research in Germany and his colleagues have come up with a way to tackle both problems. They have devised a method to extract iron from red mud by exposing it to a plasma of hydrogen and argon, and then using this iron to produce steel.

AJDIN KAMBER/SHUTTERSTOCK

Aluminium refinement produces a hazardous red sludge

Key to the process is that red mud contains between 30 and 60 per cent iron oxide by weight, alongside hazardous elements such as arsenic and lead.

The researchers heated up red mud in a device called an electric arc furnace to a temperature of roughly 1850°C, with a blend of argon and hydrogen to react with the oxygen. The resulting melt was then cooled, crushed and separated into iron pellets ready to be turned into steel (*Nature*, doi.org/gtfwqc).

Team member Matic Jovičević-Klug, also at the Max Planck Institute for Iron Research, says that given the amount of red mud there is, the process could produce between 748 million and 942 million tonnes of steel, which would result in a cut of more than a gigatonne of CO_2 compared with conventional methods. However, it would still only be a fraction of the steel produced globally each year.

Using hydrogen as part of the refining process like this isn't a new idea, says Mark Jacobson at Stanford University in California. In 2021, a Swedish consortium called HYBRIT demonstrated a trial run that lowered the carbon footprint of steel-making by up to 98 per cent. What is new is using the hazardous red mud as a feedstock, he says. "Whether it is less expensive than the first process is difficult to tell," says Jacobson. "The authors claim it is inexpensive, but more information is needed to determine this." ▮

Andrew Rosenblum

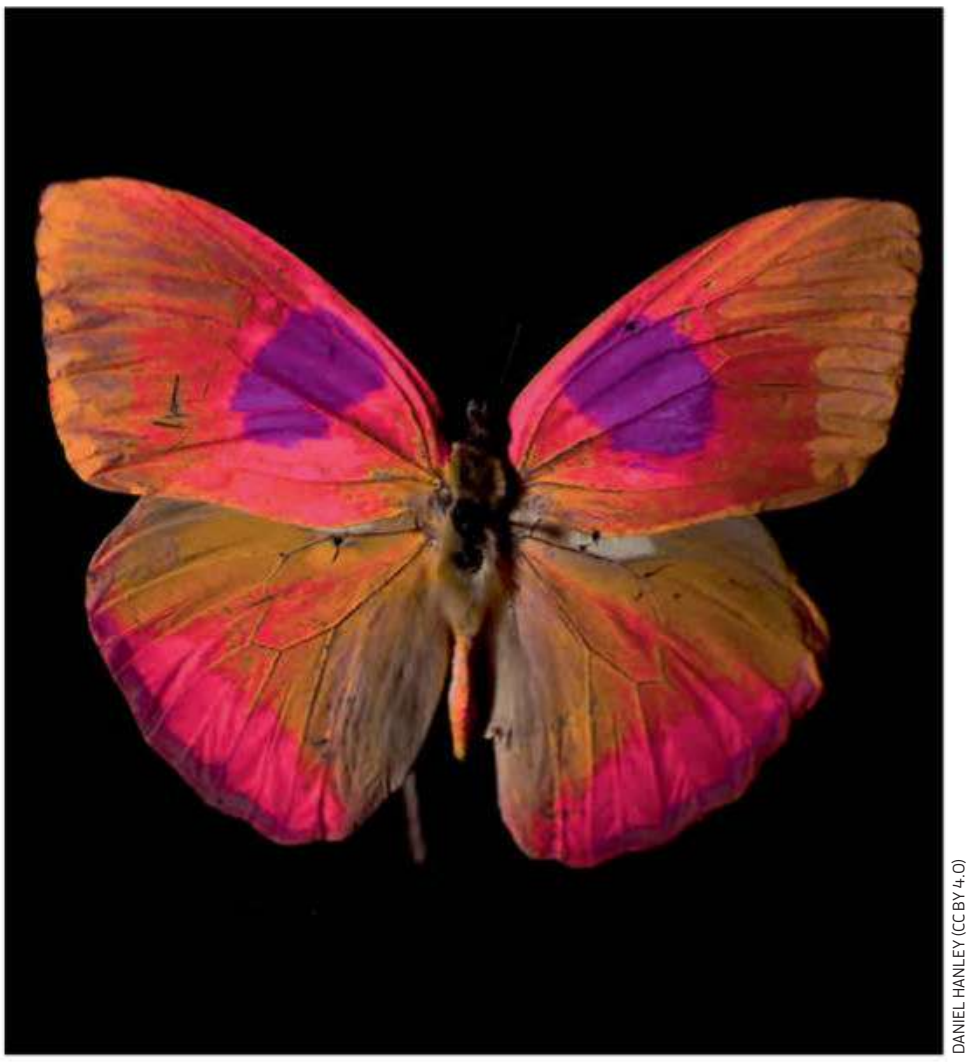
Space

Black holes may be cosmic ray source

THE most powerful cosmic rays that we see on Earth may come from microquasars, small black holes that blast out jets of material from orbiting stars.

Unlike larger quasars, which feature a supermassive black hole, microquasars contain a black hole with a star-like mass. Now, Laura Olivera-Nieto at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany, and her colleagues have observed gamma radiation from microquasar jets and think it is produced by electrons slamming into a kind of barrier and being accelerated (*Science*, doi.org/mdqw).

If this also occurs for heavier particles, then a microquasar closer to Earth could explain the mysterious, high-energy cosmic rays we sometimes see hitting our atmosphere. **Alex Wilkins**



DANIEL HANLEY (CC BY 4.0)

Mind

Putting pen to paper may boost memory

WRITING something down rather than typing it could help you retain the information better.

Audrey van der Meer at the Norwegian University of Science and Technology and her team enlisted 36 students and fitted electrodes to monitor their brain signals. The team then flashed 30 words – such as the Norwegian for hedgehog – on a screen. The students wrote down half the words by hand and typed the rest.

Writing by hand increased connectivity between central parts of the brain and the parietal lobe in the outer part, but typing didn't (*Frontiers in Psychology*, doi.org/gtfxtg). Previous work has shown such connectivity may be crucial for memory. "Handwriting uses more senses and the body is more involved," says van der Meer. "That means more of the brain is active." **Chen Ly**

Zoology

How the world looks through the eyes of other animals

MOST creatures see the world differently from us – and now it is a little easier to take a peek through their eyes.

"We went outdoors to film the birds in the trees, and only then it sunk in how bright the skies are in UV colours," says Vera Vasas at the University of Sussex in the UK. "The sky is a different colour to most of the animals than it is to us."

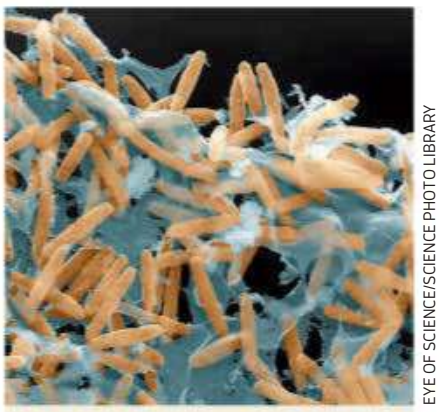
Vasas and her colleagues used two commercial cameras housed in a 3D-printed case to record videos in both visible and ultraviolet light. Then they ran the footage through software they developed to estimate which wavelengths of light specific animals see with their naked eyes. The program processes the video frames to reflect a particular animal's perspective.

The results include colourful videos showing a honeybee's view of a caterpillar revealing a hidden body part as an anti-predator display and an orange-barred sulphur butterfly (*Phoebis philea*, pictured above) as it would be seen by a bird (*PLoS Biology*, doi.org/gtfnf6).

Team member Daniel Hanley at George Mason University in Virginia says the method works with many insects, spiders, lizards, turtles, birds and mammals.

The "gold standard" for this sort of research is hyperspectral imaging, which can capture wavelengths of light beyond the visible and ultraviolet spectrum, says Jolyon Troscianko at the University of Exeter, UK. But such equipment costs more than $20,000, whereas the new camera system may cost just several thousand dollars. This could allow it to be more widely used to capture vivid animal displays. Jeremy Hsu

Really brief



EYE OF SCIENCE/SCIENCE PHOTO LIBRARY

Cold turns prey into predators

Soil bacteria *Myxococcus xanthus* (pictured above) quickly consume their prey, *Pseudomonas fluorescens* bacteria, when it is 32°C (90°F). But the tables turn if the *P. fluorescens* is raised at 22°C (72°F). Then, *P. fluorescens* "slaughtered *M. xanthus* to extinction", researchers write (*PLoS Biology*, doi.org/gtfpdq).

Tiny marsupials swap sleep for sex

Antechinus males give up 3 hours of sleep a night during their one-to-three-week breeding period before dying of exhaustion. Antechinus are shrew-like marsupials from Australia. Males live for about a year, and get one shot to mate with as many females as they can (*Current Biology*, doi.org/mdqv).

Data centre energy usage will double

Global demand for internet services and AI means the data centres that support them could double their electricity consumption in just two years, says an International Energy Agency report. They are projected to devour 1000 terawatt-hours of energy in 2026, as much as all of Japan does today.

Events

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Catherine Loveday
Principal Lecturer, BSc Cognitive Neuroscience and MSc Cognitive Rehabilitation programmes, University of Westminster

Gina Rippon
Professor Emeritus of Cognitive Neuroimaging at the Aston Brain Centre, Aston University

Views

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Intricate clocks are exemplars of sino-European trade p24

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Simon Ings dissects a new documentary by Steve McQueen p30

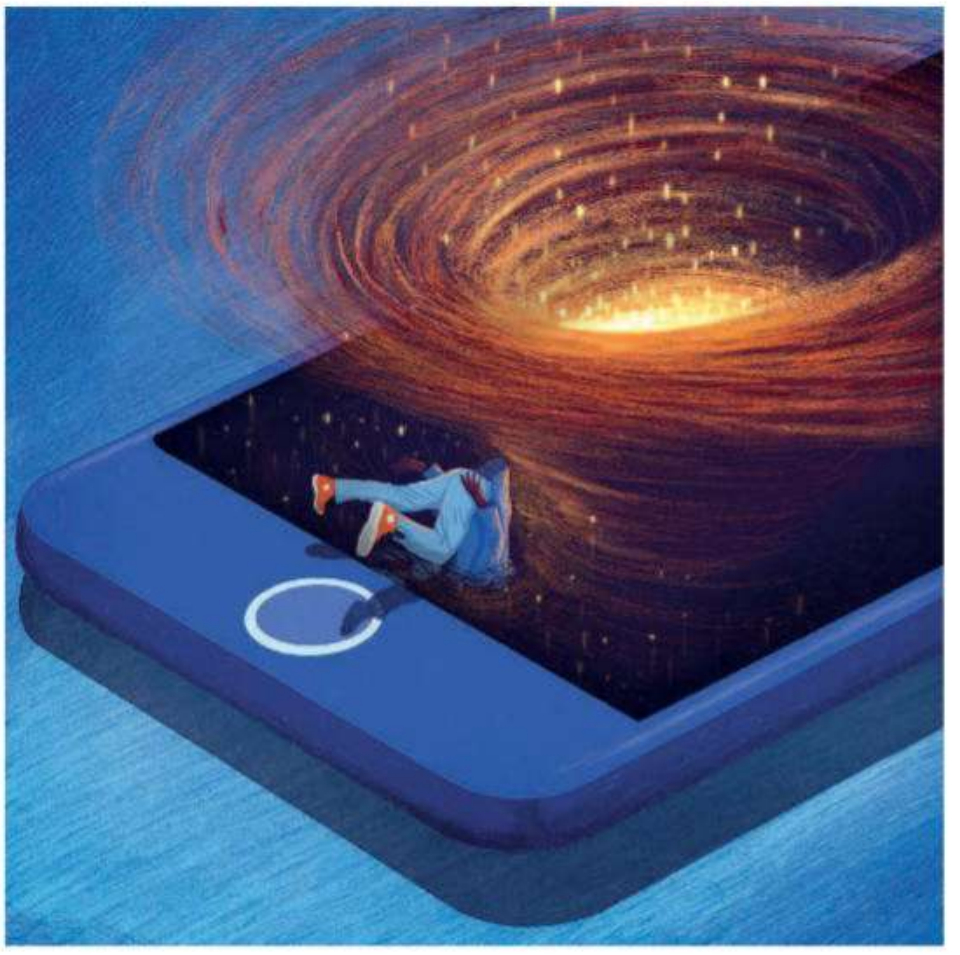
Comment

No need to detox

Describing ourselves as addicted to our phones is a counterproductive way to frame our overuse of technology, argues **Pete Etchells**

IF I asked you to describe the relationship you have with your phone, what would you say? For many, I have a suspicion that the word "addicted" would crop up in some way. For those of us who use digital technology with any sort of regularity, there will inevitably come a point where we think we have overdone it, and that doesn't feel good.

But does this really mean we are addicted to our screens? I would wager that, for the vast majority of users, the answer is no. Certainly not in a clinical sense, because there is no formal set of criteria for digital addiction. And while there are numerous studies attempting to identify and categorise people using that term, there are some fundamental problems with the research area that raise questions over what psychologists are measuring in the first place.



SIMONE ROTELLA

Back in 2020, some of these issues were highlighted by a paper in which a team used standard techniques to develop an "offline-friend addiction questionnaire". This test was given to around 800 people, and, using criteria many other studies use when attempting to classify digital addictions, the team found that 69 per cent of the participants could be "diagnosed" with an addiction to spending time with their friends.

Obviously, the aim wasn't to stoke a new moral panic about socialising. Instead, the team was showing how easy it is to create what, at face value, appears to be a data-driven measure of an addictive behaviour, yet is actually pathologising a normal part of everyday life. The idea of being addicted to offline friendships is farcical, but swap in "social media" or "smartphones" and that is what is happening in the digital technology research literature. We are stuck in a cycle of researchers conflating people's enjoyment of an activity with the idea that this means it has the potential to become addictive. This leads, ultimately, to the belief the activity is inherently bad.

It is absolutely true that we can develop bad relationships with the tech we use. But because we are stuck in a way of thinking about screens that places addiction at its core, it becomes hard to talk about the positive aspects of their use. If we want to do anything about the negatives, we are left with a single solution: abstinence. Digital detoxes are touted as a sort of panacea for many of our ills, but evidence for their efficacy is mixed at best. A recent review, for example, revealed that while some studies show positive effects, others show negative effects and none convincingly demonstrate any long-term benefits.

It is all well and good saying that we shouldn't think about our tech use in terms of addiction, but that alone doesn't get us very far. We all have moments where we feel unhappy with our screen time, and there is no one simple fix. But here is something that may help: an emerging line of research says we need to recharacterise the way we view our relationships with digital tech, not in terms of problematic use, but in terms of habits.

In and of themselves, habits, like checking our phones, are neutral. Whether they have positive or negative effects on our well-being depends not just on the type of habit, but the context in which it occurs, how frequently it occurs and what other factors might be contributing to us doing it.

Framing our tech use in this way offers us a much wider range of options when we identify the aspects of it that we aren't happy with. Rather than ditching tech altogether, we can seek ways to curate our digital experiences that promote positive effects while minimising negative impacts.

Are you addicted to your phone? Probably not. Have you developed bad habits with it? That is likely to be true for many of us. But thinking about those behaviours in terms of habit formation offers us much more power and control when it comes to developing healthier relationships with our screens. ▮

Pete Etchells is the author of *Unlocked: The real science of screen time (and how to spend it better)*, out 21 March

Health Check

Spotting the problem With measles outbreaks around the world, perhaps public health messaging should also focus on the virus's ability to suppress the immune system, says **Clare Wilson**

Clare Wilson is a reporter at *New Scientist*. She writes *New Scientist*'s weekly email newsletter Health Check, about the latest health, diet and fitness news

Clare's week

What I'm reading
Neal Stephenson's Termination Shock*, set on a near-future Earth where climate change is really starting to bite.*

What I'm watching
Ghosts*, on the BBC. The writing, acting and cast are faultless.*

What I'm working on
Tinnitus – it is surprising how such a common condition is still so poorly understood and treated.

Up next week:
Chanda Prescod-Weinstein

MEASLES is in the news again, with outbreaks being reported in the UK, US and elsewhere due to declining rates of people having the measles, mumps and rubella (MMR) vaccine. In England, the problem has been declared a national incident to help health officials combat further spread.

The reduced MMR vaccination rates are partly due to a sharp drop in uptake in the early 2000s, after false claims were made that the vaccine could cause autism, combined with people staying away from health services due to the covid-19 pandemic.

One of the first press conferences I attended, as a junior reporter in 1998, was the one where UK researcher Andrew Wakefield presented his study of 12 children, eight of whom he said had developed autism after the MMR jab. I wish I could say that I instantly perceived the claim's flaws, but I am afraid I remember finding Wakefield reasonably persuasive and charismatic. I was right, however, to leave the conference concerned about the study's impact on the public confidence in vaccines.

Since then, Wakefield's claims have been overturned by many different kinds of research, including huge population studies that find autism rates are no higher in children who have had the MMR jab than in the unvaccinated.

The current surge in measles cases means messaging about the need for catch-up measles vaccination is widespread. But there is one unusual effect of the measles virus that many may be unaware of: its ability to trigger a sustained weakening of the immune system, sometimes called "immune amnesia".

Doctors have long known that measles has a broad immunosuppressive effect, but the reason for this was only discovered about a decade ago.

In 2012, work in monkeys showed that it happens because the measles virus targets certain immune cells, including a subtype called memory B cells, which are responsible for producing antibodies against previously encountered bacteria and viruses.

Normally, these cells live in lymph nodes and the spleen for years after infections. If we re-encounter the pathogen that the memory B cells make antibodies against, they quickly start multiplying, often wiping

"Worldwide, more deaths occur from secondary infections that happen after the initial illness"

it out before we notice any symptoms. Yet when we are infected with measles, the virus takes over some of these very cells.

Eventually, members of another branch of the immune system, called T cells, start killing measles-infected memory B cells. This gets rid of the measles infection, but it also means that many of our memory B cells are wiped out, which has a terrible effect on our ability to fight off other illnesses, such as pneumonia.

Indeed, worldwide, more deaths occur from secondary infections that happen after the initial measles illness than as a direct result of the measles virus itself.

This phenomenon was studied in people for the first time in 2013, when there was an outbreak of measles in an orthodox Protestant community in the Netherlands that frowns on vaccinations.

As the outbreak began, some families let researchers take blood samples from their children both before and after their measles infection. It was a unique opportunity because most of the parents refused to get their children vaccinated, and yet they were happy to cooperate with the scientists, says Rik de Swart at Erasmus University Medical Center in the Netherlands, who led the work. His team found that the infection caused an alarming 10 to 40 per cent loss in the diversity of the children's antibodies to other pathogens. This damage didn't happen in response to receiving the measles vaccine, which was studied in a control group of children.

Other work suggests it takes about three years for people's immune systems to return to their former strength after measles.

The longer-term effects of the illness don't get that much attention, which may be partly because the Netherlands research was only published in November 2019 and, a little later, the world's virologists turned their attention to a different virus: covid-19.

Today, many of the public health messages about measles vaccination focus on the direct effects of the infection. This is understandable, given that 1 in 5 children with measles requires a hospital visit. But perhaps doctors should also be bringing measles' immunosuppressive effects to wider attention, says Simon Williams, a public health doctor at Swansea University in the UK.

Williams also points out that, in most countries, people of any age who think they may not have had the two recommended MMR doses are eligible to receive them. "It's a damaging, nasty disease, but the way it can also suppress the immune system has gone under the radar," he says. ▮

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Other worldly: clockwise from above, kayaking in Antarctica; visit Greenland; see marine iguanas and whales in the Galápagos

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ALL IMAGES VIA THE PALACE MUSEUM

Times past

Science Museum

THESE lavish antique clocks don't just represent time – they are also windows on a period of cutting-edge scientific innovation.

Each of these pieces, dating from 1662 to 1795, is part of the new exhibition *Zimingzhong: Clockwork treasures from China's Forbidden City* at the Science Museum in London. This "explores how we measure time, and the technical expertise, creativity and international trade behind these centuries-old clocks", says curator Jane Desborough.

Called *zimingzhong* in Mandarin Chinese, or "bells that ring themselves", they were brought to China by European missionaries during the Qing dynasty and were highly prized by Chinese emperors, who collected and displayed them in their hundreds in Beijing's Forbidden City palace to highlight their royal status and opulent taste.

Much of what made the *zimingzhong* so prestigious was the technology inside the intricate casings, requiring hundreds of skilled craftspeople to produce just one clock. Powered by mechanisms still used today in some timepieces, some of the complex devices may even have been used to time the duration celestial events.

The main image (far left) shows a *zimingzhong* depicting the coronation of Louis XIV, king of France, while the smaller images show others featuring (clockwise from top left): a popular Chinese art form called *penjing* ("potted landscape") with delicate artificial flowers; a miniature armillary sphere instrument displaying the movements of the stars and planets around Earth; and engravings by the 18th-century painter Joshua Reynolds. The exhibition is on until 2 June.

Gege Li

Editor's pick

All of Earth's resources are precious and finite

6 January, p 32

From Georgina Seaman, Newbury, Berkshire, UK

I realise that it might just be a turn of phrase, but I am quite concerned about the use of "unlimited" with respect to tapping magma chambers as a source of energy. It may be an unimaginable amount, but it isn't unlimited. Ask anyone who has been in space and seen the finite size of Earth. Expressions like this may result from our throwaway culture and planned obsolescence, with poor concern about waste and the squandering of our limited earthly resources.

True cost of owning a car might empty the roads

Letters, 30 December 2023

From Rosemary Sharples, Sydney, Australia

Cheaper goods in local shops, and so on, is only tinkering at the edges of the problem of excessive car use. Modern urban areas are designed, and modern life is run, with the expectation of access to motor vehicles. Perhaps motorists should pay the real costs of having a car (building infrastructure and the environmental impact) without subsidies, so we can see how much they really value the independence of having a motor vehicle.

Do good microbes thrive on a Mediterranean diet?

13 January, p 32

From John Corey, Melrose, New York, US

Your article got me thinking about indirect contributors to the Mediterranean diet's healthful properties. Specifically, with large amounts of fresh and unprocessed foods, how many more beneficial microorganisms are supported? We are learning of the importance of our intestinal microbiome: has anyone yet compared that of long-lived Mediterraneans with other Westerners? Maybe the good bugs really like olive oil!

From Tom Jones, St Austell, Cornwall, UK

It seems that the Mediterranean diet as described manages to minimise added sugars. No desserts, no sugary breakfast cereals, no sweets or cakes or pastries. And no fruit smoothies, sugary soft drinks or sugary, ultra-processed food. I assume sugary treats are allowed on occasional celebration days. Could this be the simple reason why the diet seems to be so healthy?

From Ursula Arens, London, UK

Common descriptions of a healthy Mediterranean diet don't reflect typical diets in much of the region today. For example, a reliance on whole grains better matches German and Danish diets. What's more, deaths from cardiovascular disease don't support an obvious correlation with better health. Portugal, Italy, Greece and Cyprus all have higher rates than the UK, Switzerland, France and Denmark. Drizzle olive oil onto foods and sip red wine because it is enjoyable. But not for medicinal purposes.

More diverse views needed on future of AI

13 January, p 16

From Nick Burke, Portland, Oregon, US

You report the supposed 5 per cent chance that artificial intelligence will make us extinct, according to a survey of AI experts. Asking only such people about the consequences of AI is analogous to asking only Manhattan Project scientists about the consequences of developing atom bombs.

Predicting the broader consequences requires also addressing the complex physical, biological and social dynamics surrounding AI. Influences from multiple domains will feed back into the progress of this. Yet all the reporting and analysis I have seen only includes people whose expertise is AI. That's myopic.

Capitalism may be long gone when our sun dies

Letters, 13 January

From Manek Dubash, Lewes, East Sussex, UK

Tony Green suggests that, billions of years from now, only the mega-rich will be able to afford to decamp to the moons of the gas giants to avoid the sun's expansion, while the rest of us plebs are left behind. I think he is taking too pessimistic a view about the survival of economic systems such as capitalism. I would prefer to think that we will have developed a more equitable existence by then.

Possible answers to science teacher shortage

13 January, p 21

From Geoff Harding, Sydney, Australia

It is evident that the shortage of qualified mathematics and science teachers in many countries must be addressed, or the next generation of scientists, particularly researchers, may be lost. A combination of online and live teaching is the best solution when qualified and inspirational high-school teachers are in such short supply. Perhaps the best teachers could spend one day per week at four or five schools to provide learning opportunities to many students. It may also be possible to attract retired researchers who wish to impart their considerable knowledge and experience.

Anthropocene stand does not reduce climate concern

30 December 2023, p 15

From Erle Ellis, University of Oxford, and Phil Gibbard, University of Cambridge, UK

We appreciate your efforts to present diverse views concerning the definition and application of the Anthropocene. Nevertheless, we are concerned by the closing quote of the article, which suggests that standing against defining an Anthropocene Series/Epoch in the geological time scale, as we do, is to deny anthropogenic global climate change. As scientists and as citizens who have long been deeply concerned with and active in addressing the unprecedented challenges of global climate change, we resent this suggestion.

Can't wait for great stargazing in New Zealand

6 January, p 28

From Dianne Khan, Porirua, New Zealand

When it comes to dark skies, Aotearoa (New Zealand) aims to be the world's first dark sky nation, a fact that warrants a mention. It is a lofty goal, but the country already has five dark sky reserves to enjoy while we wait for this to happen.

What we need are drastic power consumption cuts

6 January, p 13

From Bryn Glover, Kirkby Malzeard, North Yorkshire, UK

The possibility of North American electricity shortages, partly as the rollout of renewables fails to keep pace with demand, highlights what is probably the biggest stumbling block to a zero-carbon future. It is clear we have very little chance of replacing every fossil joule with a renewable joule. Therefore, we have no choice but to drastically reduce our total consumption. ▮

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The power of chance

An extraordinarily rare event could upend our lives or alter the course of history. **George Bass** takes a journey into the chaos all around us

HELEN MARIA BJORNSD/NORDICPHOTOS/GETTY IMAGES

The 2010 eruption of an Iceland volcano grounded thousands of flights

Book
Fluke
Brian Klaas
John Murray (UK)
Scribner (US)

IN HIS 1987 bestseller *Chaos: Making a new science*, James Gleick introduced chaos theory to the public. Basically, it is the study of nonlinear events and how minuscule actions can cause far-reaching disruption. Or, as actor Jeff Goldblum explained in *Jurassic Park*: "It simply deals with unpredictability in complex systems."

Brian Klaas, an associate professor in global politics at University College London, is all too aware of the unpredictability of modern life: a horrific family tragedy could have prevented his existence. His new book *Fluke: Chance, chaos and why everything we do matters* seeks to redefine history as less of a storyline, and more a "struggle to impose order, certainty and rationality onto a word defined by disorder, chance and chaos".

If that sounds defeatist, Klaas's accounts of pivotal moments are anything but. For example, he details how a 1997 Zambian coup failed when rebels were unable to hang onto the trouser leg of an escaping general, and how the atomic bombing of Nagasaki, Japan, in 1945 was a last-minute decision based on cloud cover over the original target city of Kokura, about 200 kilometres away.

Klaas maintains that our universe is a mix of convergence, which he defines as "everything happens for a reason", and contingency, or "stuff happens". And this holds true at every scale, even down to separate subatomic particles that somehow maintain a united wave function – "spooky action at a distance", as Albert Einstein called it.

Klaas speculates on the global impact of events, from the millions of people stranded when one of Iceland's volcanoes erupted in 2010 and planes were grounded to the effect on supply chains in 2021 of a single ship stuck in the Suez Canal. And then there is what Klaas sees as one of the most critical flukes: the moment

"A 1997 Zambian coup failed when rebels were unable to hang on to the trouser leg of an escaping general"

2 billion years ago when a lone bacterium became a mitochondrion, a "microscopic accident" he cites as accelerating the process of evolution.

The resurgence of populist politics may also have been indirectly caught up in the fluke effect, as leaders worry that they have no easy answers for complex questions and realise that, instead of complex analysis, "novel takes get rewarded". *Fluke* makes it clear that this kind of thinking is ultimately futile: chaos seems to lurk inside every cell of our ordered society.

One example Klaas covers in some detail is the assassination of Archduke Franz Ferdinand in 1914 – an event widely seen as having ignited the first world war – and how it was, in fact, the nobleman's third brush with death (he had survived being accidentally shot by a servant on a pheasant shoot in 1913, and a car bomb attack a year later). Would the war have been averted if he had died earlier?

Klaas shares a brutal moment of chance from his own lineage: in 1905, his great-grandfather Paul Klaas came home to find his wife had killed their four children and herself at their Wisconsin home. Paul eventually remarried, fathering the child who would become the author's grandparent.

It is a what-if moment as critical to our narrator as a giant asteroid was to Earth 66 million years ago, when its impact released a cloud of sulphur that helped to spell doom for the dinosaurs. Just a minute later, and the asteroid might have hit the more absorbent deeper ocean instead of the gypsum-rich rock under the Yucatán peninsula's shallow sea.

Can we learn to accommodate the unpredictability of the cosmos, and avoid the pratfalls that come with insisting that life follows a stable trajectory? Klaas recommends we acknowledge that flukes can be as beneficial as they can be cataclysmic.

He also warns against over-detecting patterns and striving for optimisation, which he describes as a "time bomb". As he explains with a quote from the Tibetan-Buddhist theologian Pema Chödrön: "If you're invested in security and certainty, you are on the wrong planet."

Fluke is provocative and compelling, bringing the complex relationship between order and chaos vividly alive. There is every chance you will love it. ▮

George Bass is a writer based in Kent, UK

Keeping a clear head

A leading economist argues that we can increase our overall happinesss by thinking logically. **Chris Stokel-Walker** explores

Book

Reason to be Happy

Kaushik Basu

Torva

I NEED to admit something: at times, I am an angry man.

Perhaps "angry" isn't the right word – "frustrated" is closer. The sluggishness and inefficiencies of others can spark frustration whether I am at airport security, in the supermarket or on the road. That emotion manifests as a roll of the eye or a rueful comment to myself as I wonder why people make the decisions they do, and I get frustrated when their inefficiencies affect me.

So a new book called *Reason to be Happy: Why logical thinking is the key to a better life* (the US subtitle is *On the unexpected benefits of thinking clearly*) by Kaushik Basu, former chief economist of the World Bank and a professor of economics at Cornell University in New York, should be perfect for me.

Rather than getting angry, we would do better to think logically about how to expend our energy

FLASHPOP/GETTY IMAGES

Indeed, on page 60, Basu speaks directly to everyone like me when he writes: "Anger and resentment about what others choose or do are, most of the time, pointless emotions." We would do better, Basu says, to think logically (or clearly) about what to expend our emotional and mental energy on – and to be less bothered by what other people do.

The slender book, coming in at a little over 200 pages, is Basu's attempt to bring ancient philosophy up to date for both business bros and make-life-better believers. Ancient philosophical conundrums collide with stalwarts of organisational psychology, such as game theory, to create an oddly captivating book.

Early on in *Reason to be Happy*, Basu explains that he has written his book to be dipped in and out of. However, his plain-speaking style is compelling enough to make readers tear through the first half. Here, we learn all sorts of things using logical thinking, from why we shouldn't be angry that our friends have more friends than we do, to what you should do with the information that "every ten minutes of jogging that you do increases your life expectancy by eight minutes".

Basu admits he gave up his regular jogging after deciding that he would rather spend that 10 minutes doing something he liked than trudging round parks early in the morning – a triumph of logical thinking made him happier.

However, there is a change by the second half. Basu moves from small changes that improve your life to ones requiring collective action, culminating in a grand manifesto for a better world. Unfortunately, the format grows a little... well, too logical and formulaic.

Vignettes and personal anecdotes introduce a concept; Basu gives a bit of history, then teases out an exercise that seems abstract before bringing it closer to the reader's lived experience. A thought experiment reinforces Basu's point, the lesson is learned, a new section head appears – and repeat.

It is eminently readable and far from bad, but in proselytising about the superiority of reason and rationality over emotion, Basu accidentally makes the case for the very human foibles he is trying to iron out. What makes life interesting is the unexpected – we could have done with a twist in the narrative or an unusual phrase or two here. The economist makes brilliant points and readers will learn a lot, but some of the prose and presentation is more utilitarian than exciting.

But I guess that was to be expected – and I was happy enough taking lessons from the book into my life. For instance, in future I will try to rationalise why other people wait until they reach airport security machines to unpack their liquids and electronics, and become a more patient person. It is just that I really would have been a little happier had it all been a bit less logical.

Chris Stokel-Walker is a technology writer based in Newcastle upon Tyne, UK

New Scientist recommends

Christie Taylor
Reporter
New York

I've been watching **Downfall: The case against Boeing**, a Netflix documentary about problems with Boeing's 737 Max 8 airliner that led to two

NETFLIX

crashes, in 2018 and 2019, killing a total of 346 people.

None of which is likely to alleviate new anxieties after the mid-air blowout of a fuselage panel on a Boeing 737 Max 9 last month, leading to loose bolts being found on other Max 9s. In fact, it adds wrath as you learn the full extent of how a trusted and respected company responded to demands from investors for constant growth.

Thankfully, I have also found some escape in fiction. Robin McKinley's **Sunshine** tells the story of a modern vampire hunter whose magical abilities help her use the internet to hunt evil, bend space to reach it and (even more implausibly) punch her way through a legion of mafia vampires.

Wry humour and luscious descriptions of baked goods (cinnamon rolls as big as your head) guide readers through the darkness.

The film column

Don't fence us in *Occupied City*, by *12 Years a Slave* director Steve McQueen, is an epic work that explores how a city and its people react to civil control under Nazi occupation and, 80 years on, lockdown against a deadly disease, says **Simon Ings**

Simon Ings is a novelist and science writer. His latest book, *Engineers of Human Souls*, is out now. Follow him on X @simonings

A24 FILMS

Tobogganing in the streets of Amsterdam as an act of citizenship

ARTIST and director Steve McQueen's documentary *Occupied City* unfolds at a leisurely pace. Viewers will welcome an intermission after 2 hours. If you need to make a fast getaway, that is your chance – but I'll bet that you return to your seat.

McQueen, a Londoner, now lives in Amsterdam with his wife Bianca Stigter, a film-maker and historian. The director of *12 Years a Slave* and *Shame* has created another intense work, this time based on Stigter's book *Atlas of an Occupied City, Amsterdam 1940-1945*, a monumental account of the city under Nazi occupation.

Narrator Melanie Hyams recites the book's gazetteer of the occupation address by address, while McQueen films each place as it appears today. Here is the street market where they handed out Star of David patches to the city's 80,000 Jewish residents: 60,000 of them were expelled during the second world war, and nearly all of those deported were murdered.

Outside a now busy cafe, someone once found a potato in the gutter and burned a book to cook it. At this site, in the "Hunger Winter" of 1944 to 1945, the diving boards at a swimming pool were chopped for firewood.

Though many of the buildings still stand, the word "demolished" recurs, and it is rare for McQueen's street photography not to capture some new bit of destruction or construction. Amsterdam doesn't stay still. So how does a living, changing city remember itself?

"We see the modern city beset by pandemic, as we hear it was brought to near-destruction by foreign occupation"

There are, of course, acts of commemoration, such as a royal visit to a Holocaust memorial. Other events mark more episodes in the city's history, including a ceremony apologising for its part in the slave trade. But a city's identity runs deeper than this. Do drinkers at this bar remember the Jewish people who were beaten outside their windows? Do the occupants of that flat know the previous owners were a Jewish couple who died by suicide rather than live under Nazi occupation?

Stigter's atlas is an act of remembrance. Her husband's film is different: a snapshot of how a city survives being managed and choreographed, corralled and contained. Some of *Occupied City* was shot in a covid-19 lockdown. We see the modern city beset by pandemic, even as we hear how it was brought to near-destruction by foreign occupation. McQueen's parallels aren't facile: we are encouraged to see that restrictions are restrictions and curfews are curfews, whoever imposes them, whatever their motives.

What is interesting is how people react to civil control, as it becomes (through necessity or not) heavy handed. At a big anti-fascist rally, conducted outside the city's Concertgebouw concert hall, a speaker announces: "Democracy is more fragile then ever."

Occupied City would suggest not. It is about the citizenry who survived one onslaught now coping with another – not so obviously violent, but pervasive and undoubtedly lethal. A democracy's health isn't measured in what people believe, but how they behave. And, lo, people are mostly decent. Leave us alone, and we toboggan, skate or dance. Nightmares, riots, beatings and betrayals surface only when occupiers force us into boxes.

A spirit of anarchy pervades this work: not anti-authoritarian, but just not that interested in what authority thinks. Still reeling from covid-19, it is a comfort and a challenge to be reminded that cities are, after all, nothing more than their people. ▮

Film
Occupied City
Steve McQueen
UK, 9 February; US, already released

Simon also recommends...

Film
Man With a Movie Camera
Dziga Vertov
Public domain
Vertov's hymn to urban life combines footage from Moscow, Kyiv and Odessa to create a near-ideal Soviet city.

Book
The Man in the High Castle
Philip K. Dick
Penguin Modern Classics
Dick's increasingly surreal description of an America divided between victorious Axis powers far exceeds its brief as a chilling alternative history.

Call for Nominations for the Sustainability Award 2024

Technical University of Munich

As Award Coordinating University, TUM Institute for Advanced Study (TUM-IAS) invites to submit nominations for the Sustainability Award supported by the Nobel Sustainability Trust Foundation (NST). The awards reflect sustainability in science, entrepreneurship, and politics. They are given each year to individuals or organizations whose actions are of potential breakthroughs and longstanding impact on our economy and society.

Topics 2024

- Outstanding Research and Development in the field of Agriculture
- Outstanding Research and Development in the field of Water
- Leadership in Implementation (cross-field but sustainability-related)

TUM-IAS leads the selection process with the help of international experts independently from NST. Founded in 2007 by four Nobel family members, NST promotes human ingenuity and innovation for a better society, a more sustainable planet, and economic growth.

Details on the Call for Nominations:
https://www.ias.tum.de/ias/network/nobel-sustainability-trust/call-for-nominations-2024/

Contacts:
Ms Morwenna Joubin at TUM-IAS: morwenna.joubin@tum.de / www.ias.tum.de
Ms Tracy J. Wang, CEO of the NST: tw@nobelsustainability.org / www.nobelsustainability.org

Deadline for submitting nominations: Sunday, March 31st, 2024 (12 p.m./noon CET).

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12 March, 6 - 7pm GMT, 1 - 2pm EST and on demand

Join Michael Wooldridge, a professor of computer science at the University of Oxford and a programme director for AI, as he brings a healthy injection of humility to an overhyped field and changes the prevailing narrative on AI. He will reveal how misguided anxieties distract us from the more immediate risks that this transformative technology poses – from algorithmic bias to fake news.

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Gaseous gold

Huge excitement is gathering around a clean fuel known as "gold hydrogen". **James Dinneen** tracks it down in Oman and asks if it can speed our path to net zero

AS WE drive out of Muscat, the white buildings of Oman's capital give way to an expanse of open sand ahead of the foreboding Hajar mountains. It takes us 2 hours to reach our destination, a journey that includes our SUV nearly getting stuck in the narrow back alleys of a town. But, eventually, geophysicist Ammar Alali and I arrive at a peaceful spring in the desert, surrounded by golden grasses and date palms. Alali frowns disapprovingly at a stream of bubbles in a pool of water. "It's energy going to waste," he says.

I have come here because Oman's mountains are at the forefront of a global search for a new and potentially transformative fuel, sometimes called "gold hydrogen". Colourless and odourless, this gas has good environmental credentials because it burns cleanly, producing nothing but water. Usually, however, we have to make it in an emissions-intensive process. But here in the mountains of Oman – and in places with similar geology across the world – it is naturally generated underground, potentially in vast quantities.

Proponents of using this form of hydrogen say it could dramatically accelerate our transition to net zero, which explains why researchers and start-ups are prospecting for it far and wide. Many questions remain, though, not least how much of it there really is and whether it can be easily tapped. For his part, Alali, co-founder of geological resources firm Eden GeoPower, wants to test something even more ambitious: can we stimulate the ground to boost the amount of hydrogen it produces?

Dreams of a hydrogen-powered economy have been around for decades. It would mean a world in which trucks, ships, planes and heavy industry run on the clean-burning gas instead of dirty fossil fuels. The trouble is, we currently have to make the hydrogen ourselves, which requires energy and produces pollution. Today, almost all of the 100 million tonnes the world uses annually is supplied by reacting natural gas with steam, a process that releases massive amounts of carbon dioxide. There are cleaner ways of making hydrogen (see "The hydrogen rainbow", page 34), including "green hydrogen", which is made from water using renewable energy, but these methods are currently minor players in the industry.

Striking lucky

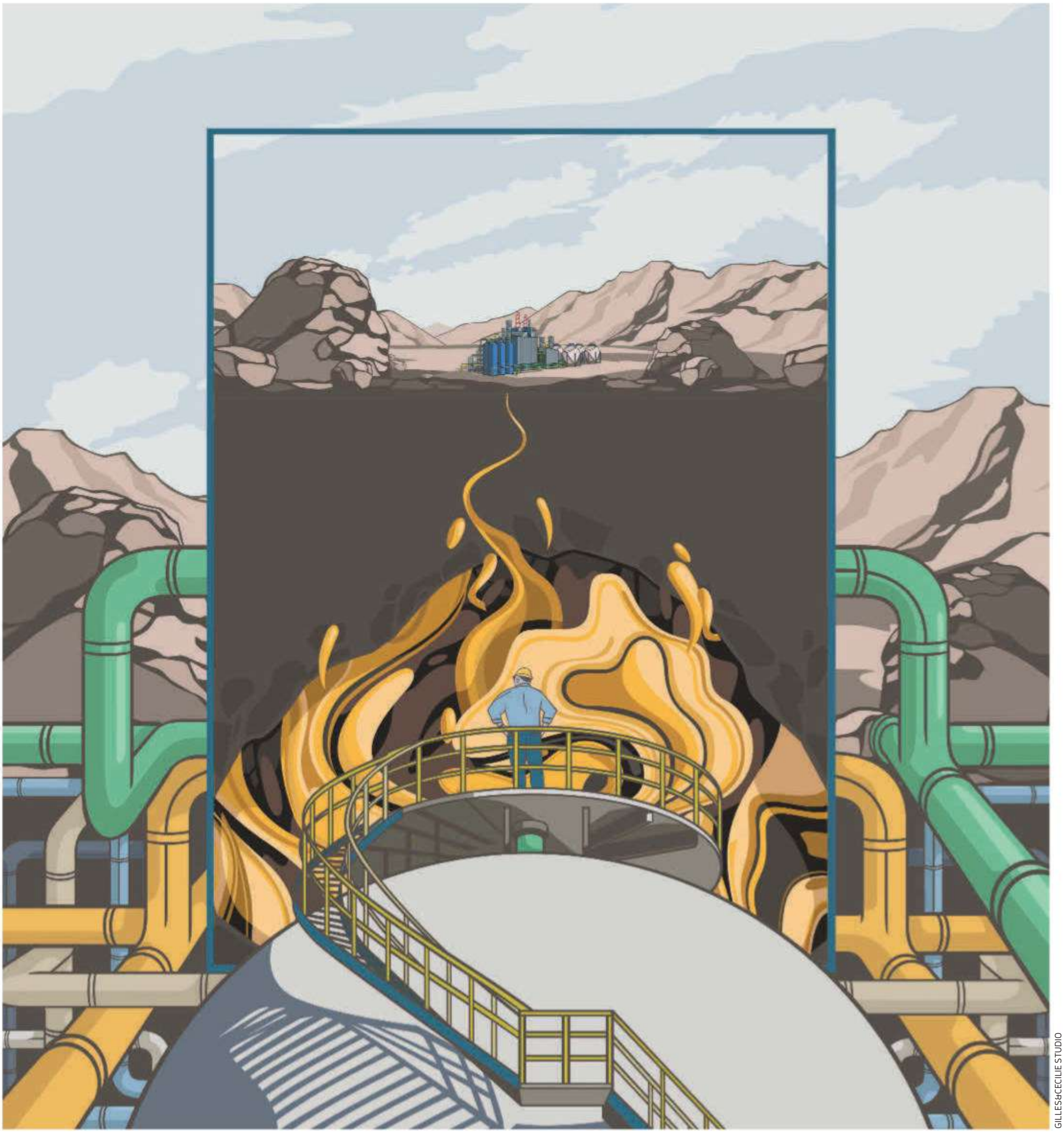
In all cases, synthetic hydrogen is best seen as an alternative way of storing energy. A natural supply might instead be a genuine source of energy. Yet despite hydrogen being the most abundant element in the universe, most researchers thought Earth's stocks of it in its gaseous form were scarce. Drillers in search of fossil fuels sometimes found it in their wells and ocean explorers saw it trickling from sea-floor vents. But no one was actively looking for hydrogen and these discoveries were considered exceptions; hydrogen was thought too reactive to accumulate in large amounts.

That assumption was challenged in 2012, when a water well close to the town of Bourakébougou in Mali was found to contain a large reserve of hydrogen. This gas occurred naturally, meaning the only energy input required in its production is that needed to collect it. This kind of hydrogen goes by several names – white hydrogen and natural hydrogen, as well as gold hydrogen – but it is most usefully called geologic hydrogen. Since that find, a flurry of prospecting has led to the discovery of what may be significant underground reservoirs in France, Spain and Australia. We have also found hints of such hydrogen across swathes of the globe (see map, page 34).

A handful of companies are drilling exploratory wells in the US, including a tight-lipped start-up called Koloma, backed by nearly $100 million from Bill Gates's venture capital firm. "There are a lot of people searching around the planet," says Eric Gaucher, an independent consultant in France who left a large oil and gas firm to pursue natural hydrogen. "One of them will find something that is very big and economic. I am convinced."

In the past decade or so, excitement over geologic hydrogen was largely confined to a few true believers in industry. Then, in 2022, researchers at the US Geological Survey revised their estimates of how much such gas there could be in the ground based on the little that was understood about how it is formed. Their modelling suggested there could be trillions of tonnes available, far more than anyone had previously suspected. If just a fraction of that could be recovered, it would be enough to meet our projected hydrogen demand for centuries. These results generated widespread media coverage. "It's gone from a fringe novelty to squarely getting everyone's attention," says Avon McIntyre at HyTerra, an Australian company focused on geologic hydrogen.

The interest may be justified. Gaucher says meeting even 20 or 30 per cent of our growing hydrogen needs with such sources would ›



GILLES&CECILIE STUDIO

free up huge amounts of clean energy that would otherwise be used to make green hydrogen. It may even be a renewable resource if it is continually generated below the surface.

But, on the other hand, there are reasons to be cautious about what has been called "gold hydrogen fever". The true amount of hydrogen the planet contains, as well as how much might be feasible to extract, remains uncertain. It is also unclear precisely how geologic hydrogen is made. Researchers think at least some is gradually seeping into the crust from the mantle below, where it built up during Earth's formation. Some may be generated by radioactive rocks splitting water into oxygen and hydrogen. Then there is the process of serpentinisation, in which groundwater reacts with iron-rich minerals in rock, such as olivine, to create iron oxide and hydrogen gas.

Most geologic hydrogen hunters have this serpentinisation process in their crosshairs. The thinking is that places with a lot of iron-rich rock may also generate lots of hydrogen, says Viacheslav Zgonnik, whose company, Natural Hydrogen Energy, drilled a well in search of the gas in Nebraska last year. The canniest prospectors look for an area of iron-rich rock capped with an impermeable layer, so the precious fuel might be sealed in and build up underground.

Other companies looking for hydrogen in the US Midwest, including Koloma and HyTerra, are following this rationale. Similarly, Gaucher says newly identified deposits in the Pyrenees mountains straddling France and Spain that could contain tens of millions of tonnes of hydrogen may occur due to a bulge of iron-rich mantle rock sitting unusually close to the surface.

In Oman, this iron-rich geology is even more accessible thanks to the region's unique tectonic past. Just under 100 million years ago, the tectonic plate beneath the Arabian Sea collided with another under the land. Such events usually result in the crust being forced down into the mantle, but here it was thrust upwards, a process known as obduction. The Hajar mountains are the result. They are the largest exposure of mantle rock on the planet, mostly made up of iron-rich peridotite that you can't help but walk upon. During my visit, in a valley strewn with boulders of this green and white-streaked material, we took off our shoes to cross a stream flowing over rocks that were once on the boundary between Earth's mantle and crust.

There may be another way to identify areas ripe for hydrogen extraction. A session at the American Geophysical Union conference last December featured research on using machine learning to identify rings of bare soil – sometimes called fairy circles – in satellite images. Joachim Moortgart at Ohio State University, who contributed to that work, says hydrogen has been measured in soil at more than 50 such circles, although

Hints of hydrogen

Some of the spots where we have measured hydrogen coming from the ground, with more in areas that have been extensively prospected

SOURCE: HTTPS://DOI.ORG/GGRC94

The hydrogen rainbow

Hydrogen may be a colourless gas, but those in the industry think of it as coming in a number of shades depending on its environmental credentials.

Black
This hydrogen is produced by degassing coal. The process produces a lot of carbon dioxide and is no longer common.

Grey
This method starts with natural gas and generates hydrogen and carbon dioxide, making it a significant producer of greenhouse gas. It is by far the most common way to make hydrogen because it is cheap.

Blue
Just like grey hydrogen, except the carbon dioxide is captured and stored underground, meaning it contributes less to global warming.

Turquoise
A relatively new innovation, this approach breaks down natural gas into hydrogen and solid carbon, meaning no carbon dioxide is emitted. It is potentially cheaper than green hydrogen (below), but the technology needs development.

Green
The most environmentally friendly way to make hydrogen. This method uses electricity generated from renewable sources to electrolyse water into oxygen and hydrogen.

Gold
Sometimes called white hydrogen (or natural or geologic hydrogen), this is when the gas occurs naturally deep underground and could be harvested through drilling, with no need to expend energy on synthesis. This potentially makes it a highly promising clean fuel, if enough of it can be found and collected (see main story).

JAMES DINNEEN

Mineral films coat pools of water in the Hajar mountains in Oman

the relationship between the gas and these mysterious formations remains unclear.

Despite the excitement, however, geologic hydrogen would have shortcomings as a fuel, especially when it comes to being transported long distances. For starters, the gas is explosive. And because it occupies large volumes, it needs to be compressed or converted into other chemicals, such as liquid ammonia, before it can be easily moved. We might need to build new pipelines to carry it from remote locations to ports or cities.

It would help if we could avoid relying on happenstance accumulations of hydrogen and instead stimulate the ground to reliably produce the gas in more convenient areas. That is what a number of researchers and companies are now working on. The US Department of Energy (DoE) is involved too, putting up $20 million for such efforts. The idea is to explore ways of speeding up the serpentinisation process and so conjure hydrogen from the ground. "We can greatly expand the regions from which this resource will be available," says Doug Wicks, who directs the DoE programme.

With their well-understood geology, iron-rich peridotite rock and clear evidence that hydrogen is bubbling from the ground, the Hajar mountains are an ideal place to test the idea. Following a workshop involving the DoE and the Omani government in November 2023, there are now plans to drill the world's first stimulated hydrogen well here later this year.

Alali, who has played a central role in coordinating this work, showed me one of four possible sites for the well. We drove through the alleys of a small town called Hailain – this was where our vehicle almost got stuck – and out into a valley. Several of the pools bubbling with hydrogen were covered by what resembled a layer of ice (pictured, above). This was actually a powdery mineral film formed from reactions between calcium leached from the peridotite and carbon dioxide in the air.

Akin to fracking

Alali told me the pilot stimulation project will involve drilling at least one borehole to a depth of between 400 and 600 metres. The rate of geologic hydrogen production will be measured and the team will then try different methods of stimulating the hydrogen-generating reaction, including injecting water and heating the rock. Adding chemical catalysts is another option, though not one the researchers plan to test yet. "There really are a lot of knobs to turn," says Alexis Templeton at the University of Colorado Boulder, who is the lead researcher on the project. She says the goal is to increase the rate of hydrogen production by 10,000, the point at which it would be commercially viable.

To help get there, the team will try a novel strategy for breaking up rocks deep underground to increase the surface area exposed to the injected water. The method, developed by Eden GeoPower, is akin to fracking for natural gas, but with electricity instead of water. Sending a high-voltage current between electrodes lowered into the ground should heat microscopic pores in the rock, causing them to expand in "a spiderweb of lightning fractal patterns underground", says Paul Cole, Eden GeoPower's head of subsurface engineering.

There are several reasons the project may not work as well as hoped. The pores in the rock could get clogged, trapping the hydrogen. The required energy input could end up being unfeasibly high. Plus, Templeton says there are communities of bacteria living in Oman's rocks that feed on hydrogen. No one knows how they will react when the amount of hydrogen increases. It is possible their numbers will swell, creating a mob of microbes that gobble up much of the fuel before it can be collected. This may not be an issue for projects drilling in hotter, deeper wells, but in Oman "the rocks are alive", says Templeton.

Outside researchers say the goal of upping the rate of hydrogen production in such wells by 10,000 is feasible, but there is no guarantee of success. "It will take some clever chemistry to make it work," says Toti Larson at the University of Texas at Austin, who isn't involved in the project.

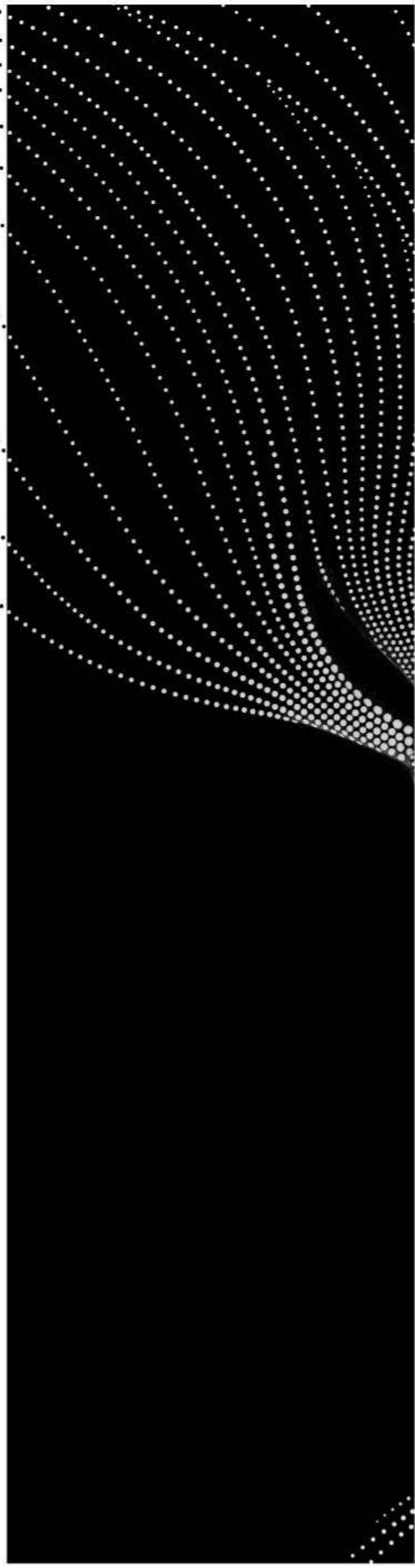
There are also some environmental risks. For instance, it is unclear how much water the project will require. Using substantial amounts in an arid place like Oman could raise eyebrows, although Alali says the plan is to use non-potable wastewater or groundwater for the tests. We also must be alive to the risk of small earthquakes from injecting water, says Mengli Zhang at the Colorado School of Mines, who also isn't a part of the work.

If all goes well, Oman, a nation known for its oil and gas, could find itself leading the field of geologic hydrogen. The impacts might even spread far beyond its borders and give our efforts to power the planet without fossil fuels a serious boost. "There are a lot of really smart people working on this now," says Wicks. "I'm expecting some audacious and potentially earth-shattering ideas about how to get hydrogen out of the ground." ▮

James Dinneen is an environment reporter for *New Scientist* based in New York

Where quantum weirdness hides

Our world emerges from clouds of quantum possibilities, but where do the other outcomes go? Maybe they are hiding in the cracks of reality, says physicist **Tom Rivlin**



ONE snowy day last year, I trekked out of Vienna, Austria, winding my way to one of the city's graveyards to visit the final resting place of a giant of 19th-century physics. Ludwig Boltzmann's tombstone features an imposing bust of the man, frowning down with a severe expression. And there above him, in gold lettering, is his formula for entropy. It must be one of only a few tombstones in the world adorned with an equation.

I had come for a spot of contemplation because I think Boltzmann's century-old ideas could help solve one of the trickiest problems in physics right now: how quantum particles, which exist in a fuzzy cloud of possible states, give rise to the solid, well-defined world of snow, leaves, tombstones and everything else around us.

There have been many attempts to explain this over the years, including the outlandish idea that the other quantum possibilities play out in many other parallel universes or that they simply vanish. But my colleagues and I suspect the answer could lie with Boltzmann.

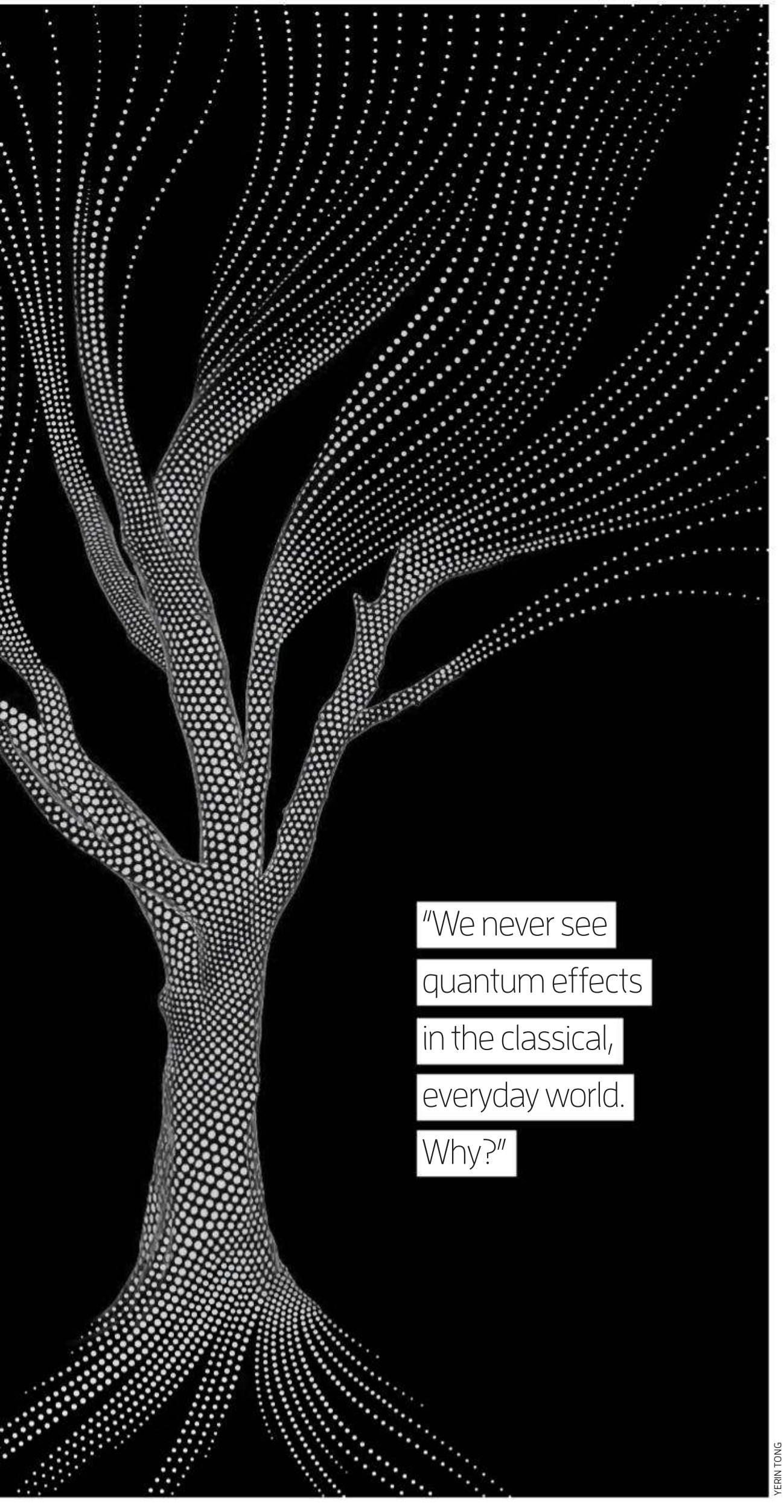
The theory he worked, called thermodynamics, is centred on entropy, a measure of how disordered things are. It explains how things cool down, power up and, crucially for our purposes, mix. It covers everyday goings-on, like milk mixing into coffee. But if we are right, its powers also extend to the quantum realm. We think those quantum possibilities are never lost at all: instead, they are just mixed so thoroughly into the cracks of reality that we can't see them. It this is true, it would profoundly change our understanding of reality.

At a fundamental level, the world lives by the rules of quantum mechanics. The theory was first developed in the early 1900s to explain why things like light and matter sometimes behave as waves and sometimes particles. Then, in 1926, Erwin Schrödinger devised a way to treat them as both, in a mathematical term called a wave function.

Quantum theory describes the microscopic world with unprecedented accuracy. But its laws are strange: they allow a particle to exist in multiple places at once, for instance. We never see these odd effects in the classical, everyday world. So, what is happening?

The measurement mystery

When physicists considered this question over the years, they often thought about measurements. No matter how many places an electron was in before being detected, once it is measured, we only ever see it in one place. Somehow, the act of measurement snaps the wave-like cloud of possibilities into a point-like reality with a defined position. This has been shown time and again in experiments. The process seems to be random and instantaneous, but physicists like me aren't completely satisfied with that, since nothing else acts this way.



YERIN TONG

Debate around how to interpret this weirdness has been raging for more than 100 years. In the 1920s, great thinkers like John von Neumann settled on the idea that, when a measurement is made, the wave function "collapses" into a single outcome, deleting the other possibilities. But this explanation, which came to be known as the Copenhagen interpretation, is far from the only reading of the situation. The many-worlds interpretation says that every possible outcome of a measurement happens, in other worlds we can't access. And physicist David Bohm's interpretation says the other possibilities never existed – they were only illusions created by our lack of information.

To make things more complicated, it has been clear since experiments in the 1970s that measurements don't just happen on lab benches. Even stray air molecules hitting electrons can "measure" them and destroy their quantumness. We call this process decoherence, and it explains why we don't see quantum effects at everyday scales: once something gets big enough, there are too many other objects flying around that can "measure" it and upset its delicate quantum properties. But the same question still applies: how precisely does this process happen?

In the 2000s, physicists Robin Blume-Kohout, then at the California Institute of Technology, and Wojciech Żurek at Los Alamos National Laboratory in New Mexico took the idea of decoherence one step further. They argued that during this process, all the information in a system, including the quantum kind, spreads into the surrounding environment. This quantum information includes the system's "two-places-at-once" property, or its superposition. But it also accounts for other intrinsically quantum features, like the bizarre, long-range "entanglement" that appears to allow instantaneous interaction between two quantum objects.

The pair's claim is that only certain types of information are easy to access after this spreading process: namely, the classical variety. The quantum information is there; it is just practically impossible to see. They named this idea quantum Darwinism, in analogy to the evolution of living things. In this reckoning, the environment around a quantum object "selects" for the classical ›

information, akin to how an environment – in a very different meaning of the word – selects for, say, long necks in giraffes.

It is a great idea, even though, in my opinion, the name doesn't quite fit. After all, it doesn't incorporate any notion of mutation and it doesn't iterate over generations. Nevertheless, this framework is a powerful way of describing the interactions between a quantum system and its environment. Until recently, however, it has lacked a rigorous description of the physical process that makes the selection happen. This is where our group comes in.

Our idea is that every step in the process can be explained using thermodynamics. And we are interested in what happens to the apparently vanishing quantum states, something that tends not to be focused on in quantum Darwinism. In a nutshell, we think this quantum information gets spread out between the object and the detector. And we think this spreading-out process mirrors the way things mix according to thermodynamics.

Now, historically, thermodynamics and quantum mechanics don't go well together. In fact, the conventional idea of quantum measurements appears to break the laws of thermodynamics. These laws, which are sacrosanct to physicists, say that energy can't be created or destroyed and that the universe becomes more disordered over time. The textbook description of a measurement seems to violate all of this. What's more, it involves deleting information: when the particle goes from being in two places at once to only one, details about the second position seem to be destroyed. This violates the conservation of information, a principle upheld by every other law of physics.

These problems were easy to sweep under the rug for decades, since we couldn't probe in detail the exact interactions between quantum objects and the thing doing the measuring. It was easy to imagine that the problem was a by-product of inaccurate modelling of the measuring "device". As experiments have improved, though, the discrepancies have become harder to hide.

The strength of our idea is that it can't help but obey the rules of thermodynamics, since these are built in from the start. "Any model of measurement should be in keeping with the rest of the laws of physics," says Sophie Engineer, who is part of our team and works between the University of Bristol and Heriot-Watt University, UK.

> "Our idea removes much of the mystique from wave function collapse"

At the heart of our idea is a thermodynamic process that Boltzmann studied called equilibration. Our group loves coffee, so we like to imagine this process by picturing a splash of milk being poured into a cup of coffee. At first, the milk is a separate blob, but as the various particles randomly move around, it rapidly spreads out and mixes with the coffee. Once the milk and coffee particles are fully mixed, it is extremely unlikely that all the milk particles will spontaneously gather up into a blob again. Eventually, the coffee-milk mixture settles into an equilibrium – we say that it equilibrates.

The laws of thermodynamics, however, say that, given long enough, the milk and coffee will spontaneously separate back into the original, unmixed state. We would probably never see this happen because it would take far longer than the age of the universe. But we do see it happen in much simpler set-ups.

We recently learned that something similar happens in the quantum world, too. In a 2018

Milk mixes into coffee through a process called equilibration

MAREN CARUSO/GETTY IMAGES

study, Jörg Schmiedmayer at the Vienna University of Technology (TU Wien) in Austria and his colleagues showed that quantum decoherence can also undo itself. They observed a few thousand ultracold atoms in a box and saw how the atoms' positions became less correlated with each other through random collisions. The amount of correlation eventually reached a low, "equilibrium" value. But, after a few milliseconds, the correlation went back to almost its initial value.

This was a brilliant result. Decoherence should destroy these sorts of correlations, so seeing them spontaneously reappear indicates that it isn't deleting information, just scrambling or hiding it. It is findings like this that inspired my colleagues Maximilian Lock and Marcus Huber, also at TU Wien, to wonder if equilibration could also underpin quantum measurements. Along with Emanuel Schwarzhans, formerly at TU Wien, and Felix Binder at Trinity College Dublin in Ireland, they collected their ideas in a framework they dubbed the measurement-equilibration hypothesis (MEH).

MEH describes measurement as a process where a quantum system interacts with a measuring device. A "device" could be anything that interacts with the quantum object, not just what we would typically think of as a measuring device. This spreads information into the device, until an equilibrium of information is reached between the system and the device. The bigger the device, the more places there are for the quantum information to hide, making it harder to get that information back – but never impossible.

How would this work in practice? Let's take the simple example of a particle in a cloud of many different locations at once. Before a detector measures that particle's position, there is information about all of the potential places it could have been detected. When the detector comes into contact with the particle, these pieces of information mix into the particles of the detector. We think this spreading process somehow "broadcasts" information from the system, making the information about its classical position available to read but its "two-places-at-once" information harder to spot.

The mathematics behind this process is complicated, so the first two papers on the framework, still in peer review, are heavy on calculations. In the first, my colleagues showed that equilibration between a quantum system and a detector can make the system look classical, while only hiding the quantum behaviour, not destroying it. But a small enough detector would still allow quantum effects to peek through. The next paper, which was led by Engineer and was the first to which I contributed, takes the first step towards connecting this to experiments, by looking at how best to extract information here.

Eventually, we would like to test our ideas in a lab, and thankfully Schmiedmayer is keen to work with our group to make this happen. With a set-up like Schmiedmayer's 2018 experiment, we could potentially watch the measurement process happen in a small system, then watch it un-happen, Lock reckons. "We could then maybe show that, as the system gets larger, the 'un-happening' gets less likely," he says. If we saw this, it would be evidence that MEH is on the right track. "That would be an extremely happy day," says Lock.

So far, we have remained agnostic about what this idea means for any of the philosophical interpretations of quantum mechanics. But our ideas do brush up against these concepts. For instance, MEH explains what happens to all the measurement outcomes you don't see – the other "worlds" of the many-worlds idea. They are all still here in our world; we just can't control the quantum system finely enough to observe them. "If we could grab hold of every single electron and control them in whatever manner we wanted, we wouldn't be asking ourselves why the particle went left or right," says Lock. "The idea of measurement becomes moot."

DRESCHER/ULLSTEIN BILD VIA GETTY IMAGES

The grave of Ludwig Boltzmann in Vienna's Central Cemetery

This would remove much of the supposed mystique from wave function collapse, since measurement only seems mysterious when we overlook just how difficult it is in practice. As Lock puts it, it is about asking: "How do I, an inaccurate, ape-sized lump-thing, try to access something as finely detailed as the spin of an electron?"

It would also rule out the idea that collapse is a physical process that deletes information, and that there is some harsh transition between classical and quantum realities. "Nobody forces you to make the classical world different from the quantum one," says Schmiedmayer. "All you can say is that, in the classical world, the complexity is too big. I just can't see the quantum part."

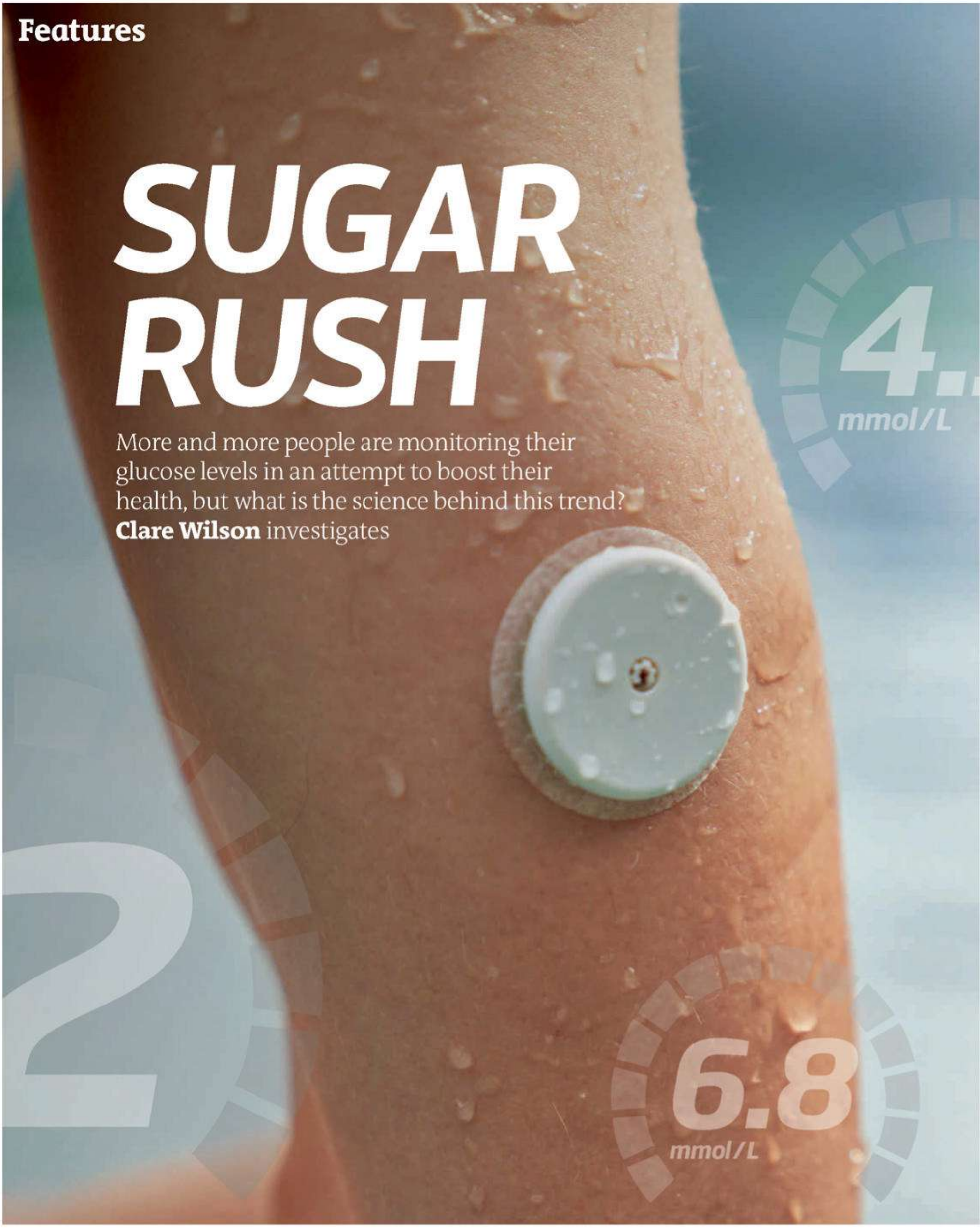
There is another possible implication of our ideas. If you take Boltzmann's ideas about equilibration to their extremes, you can imagine the whole universe equilibrating. If this is the case, some have speculated that, in the ludicrously distant future, long after the last stars die out, random fluctuations away from equilibrium will happen, resulting in sentient beings spontaneously – and very briefly – flickering into existence. This thought experiment, known as the "Boltzmann brain", suggests that equilibration isn't the end of the story for a big, dynamic system.

What happens if we push our idea to such an extreme? Well, if we could could keep track of every single subatomic particle in a detector and its environment, MEH says that you could, in principle, find all the hidden quantum information. This would almost be akin to seeing a particle in two places at once again, even after it has been measured. It is certainly an outlandish idea and I sometimes can't help wondering what Boltzmann would make of it if he were still around. ▮

Tom Rivlin is a postdoctoral researcher at the Vienna University of Technology in Austria

SUGAR RUSH

More and more people are monitoring their glucose levels in an attempt to boost their health, but what is the science behind this trend? **Clare Wilson** investigates



WIRESTOCK/GETTY IMAGES

Continuous glucose monitors measure blood sugar levels

ONCE I noticed the first, I saw them everywhere – a curious white disc stuck to the upper arm. People were wearing them at the gym, on the underground, in the office. An internet search told me they were continuous glucose monitors, which give an instant read-out of your blood sugar level.

Around the same time, I noticed media coverage of ZOE, a dietary advice programme based partly on your blood sugar responses to food, whose podcast recently topped the UK charts. And my social media feeds were filled with posts about how to hack your glucose levels. Clearly, glucose is having a moment.

We normally think about blood sugar in relation to diabetes, in which the body can't regulate glucose levels, with serious health implications. Continuous glucose monitors were invented to make it easier for people with diabetes to find out – and hence control – their blood sugar levels.

Now, however, some companies offer them to people without diabetes as part of a programme of personalised nutrition advice, seeing them as a window into an individual's response to diet that can guide the foods they should eat for optimum health. The idea behind monitoring glucose is to reduce the "spikes" that happen after eating, as this will help with weight loss and boost mood, energy levels and sleep, or so the story goes. So, what do we know about the health effects of glucose spikes? And is monitoring them a good idea for everyone or could there be any downsides? I decided I needed to dig into the research and try these monitors for myself.

Glucose certainly plays a vital role in our health. This highly soluble sugar molecule is one of the chief ways that fuel is transported around the body because it is an easy way to store and release energy. When we eat, its levels in the blood naturally rise and so the pancreas makes the hormone insulin, triggering some of the glucose to be locked down in bulky storage molecules, such as glycogen. Several hours after eating, as glucose is used up as fuel, the glycogen is converted back into glucose.

Diabetes occurs when this glucose control goes awry. In type 1 diabetes, the pancreas stops being able to make insulin, so people need to inject themselves with the hormone several times a day to prevent their sugar levels from skyrocketing. In the more common type 2 diabetes, which is often linked with being overweight, the body's cells become less sensitive to insulin. People with this version are often advised to lose weight and to avoid foods high in sugar or starch, which the body quickly breaks down into sugar.

Both types can have health consequences. If someone's blood sugar falls too low, they may faint or even fall into a coma. But if it is consistently too high, glucose can stick onto larger proteins inside their cells and even their DNA, fouling up myriad metabolic processes. Over time, this can lead to kidney disease, blindness and blood vessel damage that can cause heart attacks and strokes. A pivotal study in 2000 showed that people with type 2 diabetes who keep their glucose levels lower, on average, had fewer of these health problems.

Continuous glucose monitors arrived in 1999 to help those with type 1 diabetes know how much insulin to inject without doing lots of blood tests a day. Now, a sensor on the arm estimates the glucose level in the fluid between cells, which is very similar to that in the blood, and sends continuous signals to a phone app. "They have been game changers for people with type 1 diabetes," says Shivani Misra, a diabetes specialist at Imperial College London. They can also help people with type 2 diabetes. David Unwin, a doctor based in Southport in the UK, says glucose monitors help some of his patients with diabetes maintain a good diet. "It causes you to think a lot more about what you're eating," he says. "You see that those biscuits put up your blood sugar."

Surprisingly painless

Intrigued to see if there were any interesting patterns in how my blood sugar levels changed throughout the day, I decided to try out two glucose monitors, one provided by ZOE, which offers glucose monitoring along with some other tests, including a gut microbiome analysis, and one by a service called Lingo from Abbott that focuses on blood glucose. When the first arrived, I was taken aback by the almost 1-centimetre-long needle. But applying it was easy and surprisingly painless, and soon I was brandishing two monitors, one stuck to each arm. I should say that I didn't try the diet coaching aspect of either programme.

The good news is that for the two weeks I wore the monitors, my glucose values stayed well within the target range of 3.9 to 10 millimoles per litre, usually taken as the ideal lower and upper limits for people with diabetes. And my personal report from ZOE said my glucose control was excellent. But that didn't ›

mean I could necessarily relax. Within that range, I experienced many ups and downs. Occasionally after eating a big meal, such as a pasta dish or a curry with rice and naan bread, my glucose rose by more than 1.7 mmol/L, which is one of Lingo's definitions of a spike.

Seeing these spikes was worrying, so it was time to take a closer look at the evidence that they are bad for people without diabetes. The firms behind these programmes typically point to long lists of studies that suggest links between higher blood sugar and poor health. "If you are having multiple spikes in a day, your mean glucose level will be raised. We know that raises your risk of diabetes and heart disease," says Tim Spector at King's College London, one of the founders of ZOE. A spokesperson for Lingo pointed me to a review of 38 studies showing that in people without diabetes, those with higher glucose levels were more likely to later develop heart disease, arguably the most serious risk of poor blood sugar control.

But there are two caveats for anyone taking this kind of research as evidence that we should all be trying to minimise our glucose spikes. The first is that most of these studies merely observe correlations between high glucose and poor health outcomes – and that doesn't show the former causes the latter. The correlation could be caused by a third factor: for instance, people who have a more sugary diet could be more unhealthy in other ways, and that might be behind their poor health. This is a wide-ranging problem with dietary research.

The second caveat is more subtle. Glucose levels jump up and down many times over the day, so there are several ways they can be quantified. The studies in the review that found a higher risk of heart disease used several common measures, including the "A1C" test – which reflects someone's average blood sugar over many weeks – and people's response to a standardised sugary drink, which measures increases in blood sugar that last for at least 2 hours. But much of the negative talk about spikes implies that any rises are harmful, even brief ones, says Misra. "It is totally normal for your blood sugar to go up if you eat carbohydrates, and then to come down again, because the pancreas has made insulin."

What's more, we still don't know how high a spike is too high. Most of our knowledge about blood glucose comes from studying people with diabetes and it is unknown if the same figures apply to those without the condition, says Misra. "We do not have that data for healthy people because we've never had these devices before," says Nicola Guess, a dietitian at the University of Oxford.

> "If you focus on any single metric, such as only blood sugar, you are only seeing a very small piece of a huge puzzle"

A well-balanced diet (right) can help avoid the sharp blood sugar spikes typically seen with sugary foods such as doughnuts

When it comes to the other claimed benefits of reducing spikes, research has begun to accrue suggesting that high glucose levels are linked with lower sleep quality and lower mood and energy levels. But it is still early days, with most of the studies so far being small ones that observe correlations. The best kind of evidence would be a large, randomised trial showing that people who limit their glucose spikes have better sleep, for instance.

Glucose dips

Another central claim is that avoiding glucose spikes and subsequent dips can help with weight loss. One study of 1070 ZOE users found that some people are prone to big dips in glucose 2 to 3 hours after eating. This correlated with them feeling hungrier and eating more calories overall that day, says study co-author Sarah Berry at King's College London, who is also chief scientist at ZOE. In fact, using a glucose monitor told Berry that she experienced this effect. "It was a real eye-opener, putting together how I felt with what's going on inside my body," she says.

Sceptics say that this is something we don't need a blood test to measure. "People already have their own bodies to tell them: 'I'm hungry. I didn't sleep well,'" says Dawn Davis, a diabetes specialist at the University of Wisconsin-Madison. "The reality is most of the information they're going to get from [a monitor] is probably things that they could have figured out on their own."

Others counter that monitors help people see what is happening. "These devices can really train you to see what's going on," says Michael Snyder at Stanford University in California, who is co-founder of a glucose coaching app called January AI. Using them lets people avoid the foods that cause the biggest spikes, he says.

Given we already know that sugary foods cause a rise and then dip in blood glucose, why do we need monitors to tell us individually which foods have the biggest effects? The argument here is that different people have different blood sugar responses to the same foods. One study by ZOE of 1002 people without diabetes, for example, showed this was the case – even for identical twins. That was borne out by my own experience, when I had a slightly higher spike compared to that of my partner, who was also wearing a monitor, after eating a roast chicken dinner.

Yet it is unclear whether these divergences are consistent or even meaningful. One study that has yet to be peer-reviewed looked at 30 people without diabetes and found that a person's glucose rise in response to the same meal on two different days could be as different as their reaction to different meals with varying carbohydrate content. "It's probably more variable than people think," says study co-author Aaron Hengist at the US National Institutes of Health. Even differences between the monitors could have an effect – Lingo's device generally gave me higher readings than

L: NATALY STUDIO/SHUTTERSTOCK; SHUTTERSTOCK/RAWPIXEL.COM

ZOE's, occasionally by as much as 0.8 mmol/L.

A few studies have started to look specifically at whether glucose monitors or personalised nutrition advice can help with weight loss. One, in 40 people who were overweight and didn't have diabetes, compared a group who received in-person dietary advice alongside a continuous glucose monitor with a group who received only the advice. After eight weeks, the group with monitors each lost 3.1 kilograms, on average, compared with an average of 2.3 kg in the other group. The team concluded that the monitors helped people shift their diets.

Data from a much larger randomised trial carried out by ZOE was presented at the 2023 European Nutrition Conference in Belgrade, Serbia, comparing people who followed its full programme, logging their food intake every day and receiving ongoing advice through the app, with people who received a leaflet and online resources containing healthy dietary advice, a video lesson explaining the advice and regular check-ins by email to encourage adherence. The control group also had access to coaches by email, but not to the same level as those on the ZOE programme.

The study found that those who used the ZOE programme improved slightly on several metabolic parameters compared with the control group, and that after four months they had lost 2 kg compared with a 0.3-kg gain in the control group. But this arguably wasn't really a fair comparison, as trials of different weight-loss programmes inevitably find that people succeed in losing more weight when they get more advice, attention and support, says Guess. Spector says that this inequity is inevitable when comparing any personalised nutrition programme to standard dietary advice. "It's common practice in trials to compare with the industry standard."

Some might argue that a 2-kg weight loss after four months isn't that impressive. Spector says the goal of ZOE isn't rapid weight loss but to get people eating more healthily long term.

To be fair, most diets don't produce much weight loss in randomised trials, so you could argue that this approach is on par with any other diet. But the focus on blood sugar concerns some dietitians, such as Guess, because to prevent spikes, people might be tempted to avoid foods that are high in sugar and starch – a low-carb diet, in other words.

Finger prick tests used to be needed many times a day with type 1 diabetes

TINT MEDIA/SHUTTERSTOCK

The question of whether a low-carb diet is healthy has long been debated. Traditional dietary advice says we should base meals around starchy foods like wholemeal bread, pasta, rice and potatoes. People on low-carb diets, however, tend to get more calories from proteins and fats, whether from meat, dairy or plant sources. "I worry that dietary advice that actually does something that we need it to – lowering blood pressure, lowering cholesterol – is being subverted by [concerns over] blood sugar in people who have no reason to be concerned about their blood sugar," says Guess. "People are being prompted to focus on a non-existent risk factor, potentially to the detriment of actual risk factors."

"If you focus on any single metric, such as only blood sugar or only blood fat, you are only seeing a very small piece of a huge puzzle," says Berry. "That's why, at ZOE, we use multiple inputs to generate our food-based advice."

Where glucose monitors are less contentious is in potentially helping to identify people with diabetes and pre-diabetes, in which glucose levels are higher than average, but below the threshold for diabetes. Doctors offer cheap and simple tests for these conditions, but many people don't receive them as they don't have regular check-ups. It is possible that the craze for glucose monitoring could help spot extra cases by encouraging people to see a doctor.

As for me, I wasn't sorry to take the monitors off and stop worrying about my spikes. While the evidence about the benefits of limiting them in people without diabetes is still unclear, there is more certainty around A1C tests, because they reflect long-term glucose averages and, fortunately for me, my A1C estimate from ZOE was below the level indicating pre-diabetes. I'll take that as a reassuring sign – although I suspect I will be checking in on my score in the years ahead – not with a commercial dietary programme though, but with my doctor. ▮

ZOE and Lingo provided the monitors and access to their programmes free of charge

Clare Wilson is a health reporter at *New Scientist*

The back pages

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60-second psychology

All's well that ends well

Finishing your work session with a pleasant task boosts motivation and increases overall job satisfaction, discovers **David Robson**

David Robson is an award-winning science writer and the author of *The Expectation Effect: How your mindset can transform your life*

WHEN I first aspired to become a science writer, I imagined each day would be filled with inspiration and creativity. The reality, of course, is far less enjoyable than my fantasies. Researching a story, for example, often involves reading a lot of dry, technical papers before I finally strike gold with the information that I seek.

Most professions, I imagine, include challenging but necessary tasks that sap enthusiasm. But a recent paper from Edward Lai at the Hong Kong Polytechnic University and his colleagues may offer us all a way to boost our motivation. It is called the "easy addendum effect", and, as the name suggests, it involves ending each work session with a more pleasant task that will be relatively straightforward to complete.

The strategy was inspired by a phenomenon known as the "peak-end rule", which means we often judge events by the way they finish, rather than the overall experience. In one seminal experiment, Daniel Kahneman and his colleagues asked participants to plunge their hands into water at unpleasantly cold temperatures. Some simply held their hands in 14°C (57°F) water for 60 seconds, while others were given a further 30 seconds in water at 15°C (59°F). Surprisingly, most preferred the second option. It seems their memory of the experiment only focused on the last moments, which was slightly more pleasant in the 90-second set-up. As Shakespeare put it, all's well that ends well.

OSCAR COSTA/ALAMY

The research on the easy addendum effect suggests that our impressions of work fall prey to the same bias – and we can use that to our advantage. Lai's team gave participants a series of tedious tasks – from flexing their muscles against heavy weights to sorting books into alphabetical order or answering customer complaints. In each case, participants performed the tasks with or without an "easy addendum" tacked to the end of the job. Those testing their strength were given a few extra rounds of lighter weights, for instance, while those answering customer queries tackled some more straightforward requests.

Much like the ice-bath experiments, there was no logical reason why loading on additional work to an existing task should make it more pleasant overall. But the researchers found that the "easy addendums" significantly reduced the perceived difficulty and increased participants' satisfaction with their jobs.

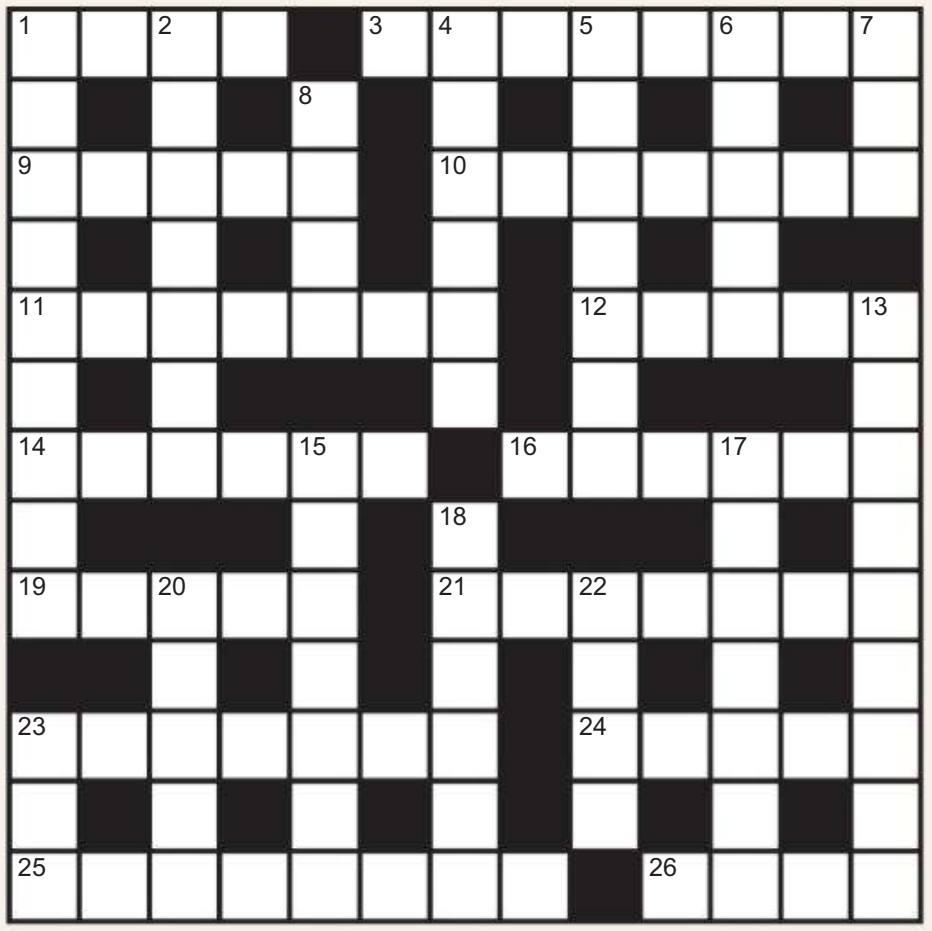
Since learning about Lai's research, I have tried applying this strategy to my own work. Writing is still my favourite part of the job, and so this column was a pleasant addendum to an otherwise gruelling day of research for another article. By putting these words on the page, I feel far more energised about the work behind me – and readier to enjoy the evening ahead. ▮

These articles are posted each week at newscientist.com/maker

60-second psychology appears monthly

Next week
Stargazing at home

Cryptic crossword #128 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Unleash Pomeranian, finally secured by animal doctor (4)
3 Plan Tim's new artificial hips, for instance (8)
9 Devise door for ship's deck (5)
10 Get hot ore processor, rotating mass 180 degrees (7)
11 A collection of cells under consideration (2,5)
12 I took the reins after Dee did nothing (5)
14 With leader absent, use identical source of oil (6)
16 Light breakfast fare includes bit of egg (6)
19 In broadcast, wind up powerful person (5)
21 Assemble half of colony after hours (7)
23 Opening core's interior provided diamonds (7)
24 Jewels containing last of killer bugs (5)
25 Explodes target concealing guide (8)
26 Modify New York setting in summer to include island (4)

DOWN

1 Wearable device harvested bananas (2,7)
2 Large rodents destroyed Saturn I (7)
4 Viral image involves single retired physician associated with "animal magnetism" (6)
5 Current casual shirt created a false impression, per Spooner (3,4)
6 Regarding delivery that is missing from actress Portman... (5)
7 ...address seemed illegibly rendered, initially (3)
8 In this way, temperature rises in simple dwellings (4)
13 Craft denser tin plates (6,3)
15 Ruined shrine found south of medium-sized standing stones (7)
17 Blackened leafy vegetable on tongue (7)
18 Model clothing line donated to Society for Creative Anachronism (6)
20 Small group flipped soil around area (5)
22 Blocks part of a race circuit (4)
23 Predator beheaded chicken (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #237
set by Bethan Ackerley

1 Which was the earliest age in the Holocene Epoch: the Northgrippian, the Greenlandian or the Meghalayan?

2 Which natural satellite of the asteroid Didymos was targeted by NASA's Double Asteroid Redirection Test?

3 In which city was the ancient Greek polymath Archimedes born?

4 What is the smallest living crocodilian species?

5 What name is given to loss of muscle strength associated with ageing or immobility?

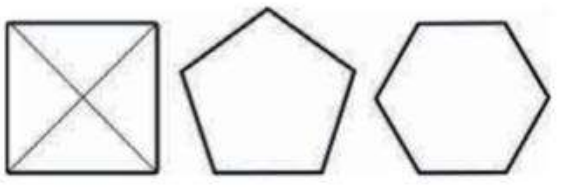
Answers on page 47

BrainTwister
set by Katie Steckles
#5 Diagonal lines

A square has two diagonals (lines that run from one corner to a different corner, but not between two corners on the same edge).

How many diagonals does a pentagon have? What about a hexagon?

What kind of regular polygon has a number of diagonals that is three times the number of its corners?



Solution next week

Oops I did it again

Humans make mistakes, but how often do other animals? Are some more prone to errors and do they learn from them?

David Bortin
Whittier, California, US
"To err is human"? Wrong! To err is life. Everything that has ever lived has been a product of natural selection. Those that learn from their mistakes survive. Even the lowly virus responsible for covid-19, which is only debatably living, is so much in the news because it keeps evolving, or learning from its mistakes.

Among wild animals, birds' mistakes most often make the headlines, by flying into window panes and windmill vanes. But since their biggest mistake is that they don't carry accident insurance, we rarely hear about the non-fatal incidents, so the data regarding learning is skewed.

My knowledge of other animals has mostly been acquired through observation of my two cats. Their

"Cats are notorious for getting stuck in inaccessible places, though I have seen them learning from their errors"

antics rival the best of the Three Stooges or the Keystone Cops. But I have never seen them blush, and they are masters of body language that declares "I meant to do that!", so maybe they did. And since cats are the most nearly perfect of all animals, they must make the fewest mistakes, right?

Caroline Peters
Wokingham, Berkshire, UK
Animals certainly do make mistakes, and cats are notorious for getting stuck in inaccessible places, though I have certainly observed them learning from their errors.

We acquired a cat who had always lived indoors. When he first went out into the garden, he made some horrible mistakes. He climbed a pine tree and had to be rescued as he couldn't work out how to climb down. He also tried to catch the jumbo jets that flew overhead. Although he wasn't a very bright cat, he never repeated the tree escapade and very quickly learned that chasing insects was far more rewarding than trying to catch jumbo jets.

Another, much more intelligent animal wore a collar with a magnetic tag to let him in through the cat flap. When he broke his collar and couldn't get in, he went back to where he had lost it, retrieved the collar in his mouth and was able to get in and out through the cat flap by picking it up each time, until we came home and provided a new collar.

Peter Meehan
London, UK
Animals that care for their young limit their own dangerous errors, then teach their offspring how far to take hazardous experiments, or how to learn. If the species is prone to missteps, greater reproduction must counterbalance consequent wastage from the death rate.

Ron Dippold
San Diego, California, US
Yes, other animals make mistakes, and learn from them. Young animals such as puppies and kittens make the most errors – they lack any coordination or knowledge, so it is how they learn. Thankfully, they are very resilient, so even after spectacularly misjudging a jump and going face first into the side of a box, they just get right back up and do it again, hopefully better.

With tiny, "primitive" animals – say, a tardigrade – it can be hard to tell if something is truly a mistake, but all small to largish animals observable with human eyes have been seen making obvious mistakes.

Penguins trip and fall, primates miss branches, rats fall off perches, elephants get drunk and rampage and fall over (sometimes hurting themselves, which truly makes it a mistake), cows and fish get stuck, bats smash into things while flying, birds miss their perches or knock over the bowers they are building, even spiders sometimes miss their jumps or go so far into a threat posture that they actually fall from their webs. Anything going after a skunk or porcupine is likewise probably making a mistake.

But this is how all creatures learn. Older animals that survive making mistakes tend to be savvier, though some deliberately risk the same behaviours because they find the rewards are worth it, such as a chance at mating.

Cognitive mistakes seem to be harder to overcome than physical mistakes. If you miss a jump, now you know better. My cat recently slipped off a counter while sleeping – luckily he was unhurt, but he doesn't sleep up there any more. On the other hand, I know someone who has been getting burned by get-rich-quick schemes for over 30 years and will never learn.

SHUTTERSTOCK/ORLA

Could a time-travelling human survive during the time of the dinosaurs, or perhaps earlier?

This week's new questions

Safe time travel **When I invent a time machine, what is the earliest period in Earth's history in which I could comfortably survive?** ***Derek Couzens****, Westgate-on-Sea, Kent, UK*

Balancing act **Is there exactly the same number of electrons as there are protons in the universe? Is that also true of Earth at any given moment?** ***Tim Blake****, Perth, Western Australia*

Enough for tomorrow

Why are leftovers from a hot meal always tastier than the original meal when they are heated up the next day?

Mark Thompson
Tewkesbury, Gloucestershire, UK
Not all leftovers improve with time. Certain dishes, especially

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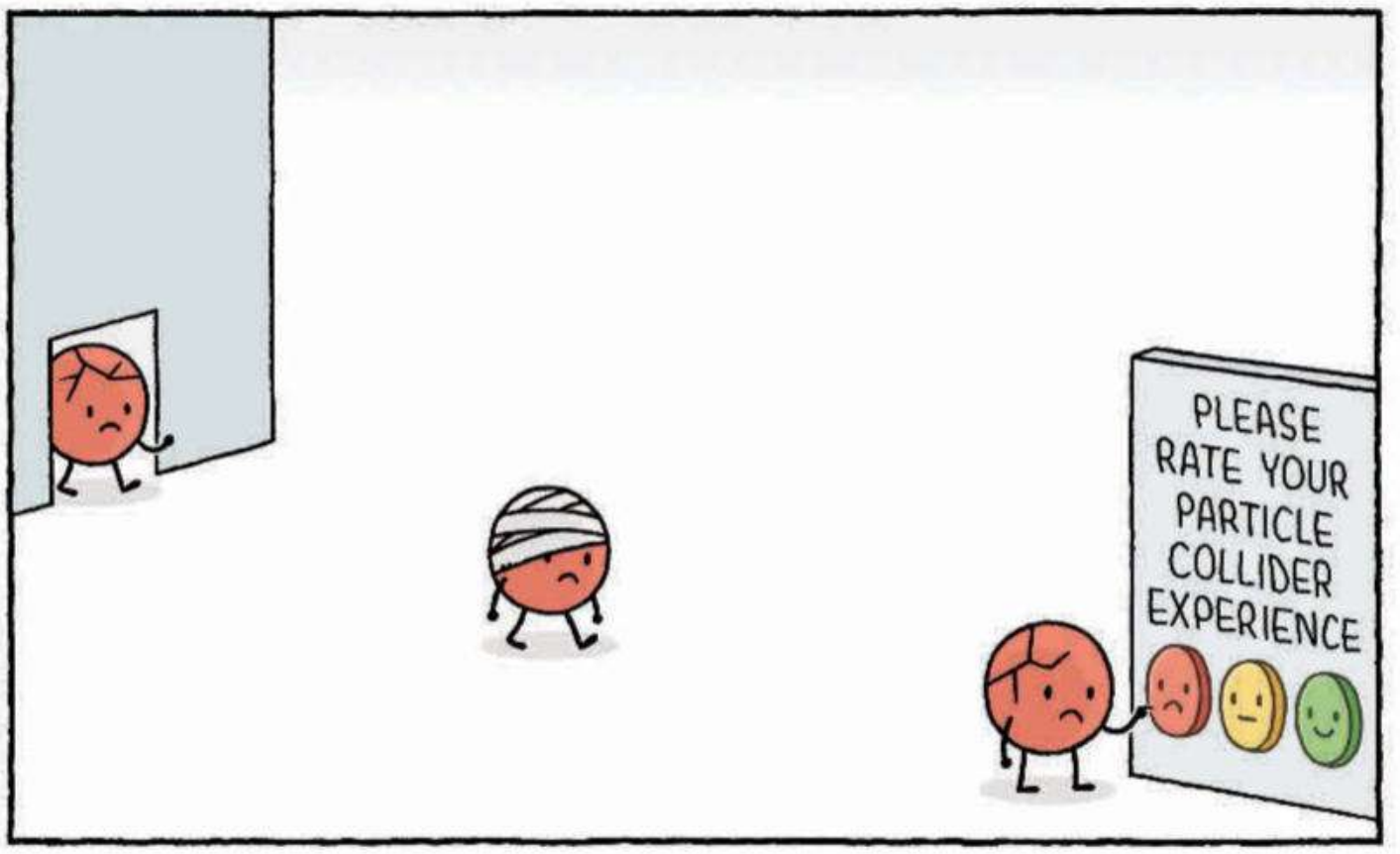


those with delicate textures or ingredients that degrade quickly, may not fare as well after reheating. However, a number of factors can contribute to an enhanced flavour profile when reheating stews, casseroles, curries and similar dishes.

As a dish sits, the flavours have more time to meld together. This can result in a harmonious and balanced taste, as the different ingredients have had more time to infuse their flavours into the entire dish.

Leaving the dish to sit also allows the flavours to penetrate and marinate the ingredients more thoroughly. This can enhance the overall taste and make the dish more flavourful.

Some chemical reactions, such as Maillard browning, continue to occur even after cooking. When you reheat the leftovers, these reactions can lead to the development of new and complex flavours, making the dish more delicious.

There is also a psychological aspect to the perception of taste.

"The positive experience associated with the initial meal can enhance the enjoyment of the reheated leftovers"

Anticipation and the memory of a delicious meal can contribute to the perception that leftovers taste better.

The positive experience associated with the initial meal can enhance the enjoyment of the reheated leftovers. For me, pizza is always best the day after – it reminds me of the halcyon days of university.

Ianthe Maclagan
Oxford, UK

I can think of two reasons. One is that the flavours have had time to blend together.

The other is that, if you are the cook, smelling the flavours of the meal while you are cooking it desensitises you to its full taste. The next day, you come fresh to it and can taste it properly.

Left or right?

Why aren't we equally capable with our left and right sides? Wouldn't this have given us a survival advantage? (continued)

Tim McCulloch
Sydney, Australia

Tony Seikel gave a fascinating description of some features of lateralisation in the human brain's left and right hemispheres (Last Word, 30 December 2023), as well as an explanation of why this occurs.

However, I don't think he really addressed the original question, which was why we didn't evolve to be just as skilful with both sides of our body.

I wonder if the answer lies in a trade-off with the extra cortical resources that fine motor control, for example, requires.

Any extra survival benefit from having both sides equally skilful might just not be worth the cost. Besides, making everyone's left hand dexterous would be unacceptably oxymoronic. ▮

Answers

Quick quiz #237 *Answers*

1 The Greenlandian
2 Dimorphos
3 Syracuse, in what is now Italy
4 Cuvier's dwarf caiman (*Paleosuchus palpebrosus*)
5 Sarcopenia

Quick crossword #150 *Answers*

ACROSS 7 Beriberi, **9** One-way, **10** Beta, **11** Madagascar, **12** Tendon, **14** Selenium, **15** Doppler effect, **17** Schemata, **19** Log off, **21** Subspecies, **22** Hole, **23** Almost, **24** Toadflax

DOWN 1 Red-eye, **2** Pica, **3** Terminal, **4** Googol, **5** Heisenberg, **6** Catapult, **8** Industrialist, **13** Depression, **15** Decouple, **16** Feldspar, **18** Alerts, **20** Fulmar, **22** Hi-fi

#4 Addition subtraction *Solution*

For the four-number case, we can do 12 + 34 = 43 + 2 + 1.

For the five-number case, while 12 + 34 + 5 = 5 + 43 + 2 + 1 will work (deleting the same pluses as before), you can also do 12 + 3 + 45 = 54 + 3 + 2 + 1.

Space politics

The UK is successfully playing catch-up with the US in boosting politicians who speak knowingly of the vast, mostly empty depths of the universe.

The UK's new space minister, Andrew Griffith – his official title is minister of state for science, research and innovation – granted an interview to Tali Fraser of *The House* magazine.

Griffith apparently gave her a demonstration of how education happens: "He points to the suspended sphere in the Science Museum that switches appearance from planet to planet and declares 'now we have got Mars!' only for an employee to gently tell him it is, in fact, the Sun. Undeterred, Griffith exclaims 'that one is Saturn!' as the planet changes. The employee interjects: 'No, no, that is Jupiter!'"

Back in 1991, one of the very first Ig Nobel prizes was awarded to then US vice president Dan Quayle. Quayle had been given extra duties, becoming chair of something called the National Space Council. He was often in the news for educating the public with statements such as the following:

"[It's] time for the human race to enter the solar system."

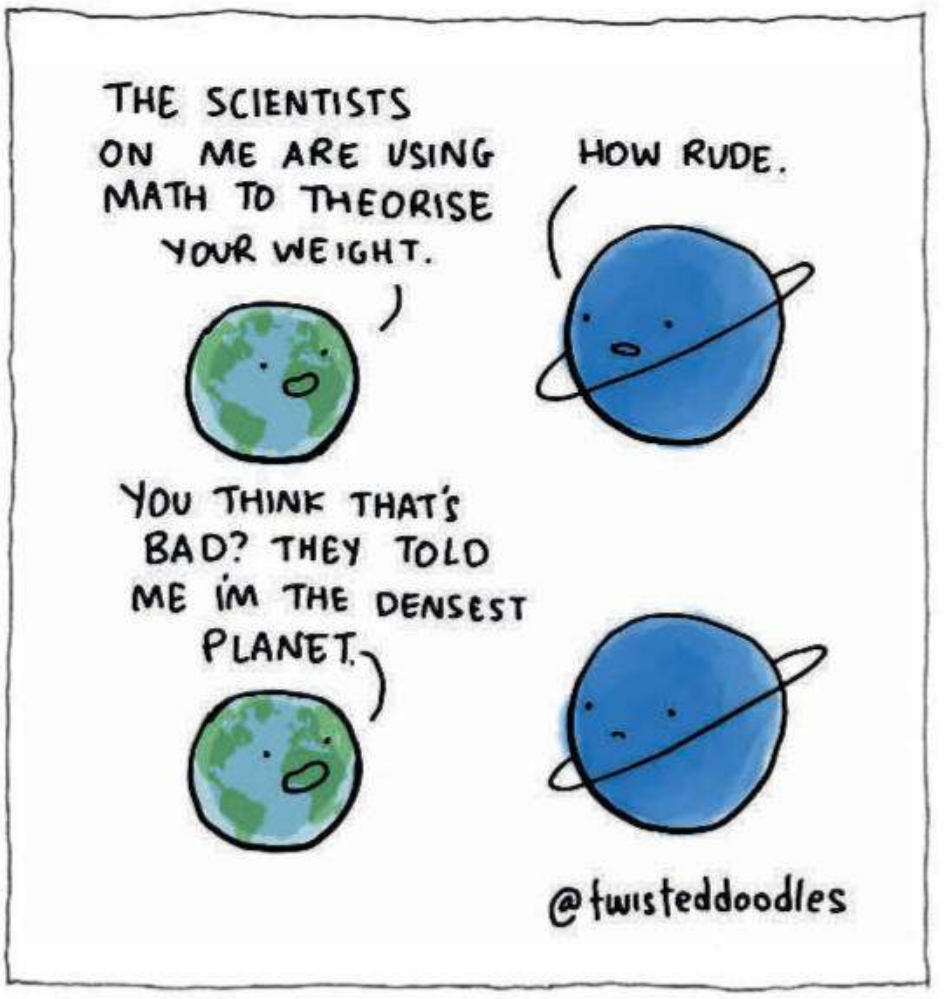
"We have seen pictures [of Mars] where there are canals, we believe, and water."

"People that are really very weird can get into sensitive positions and have a tremendous impact on history."

The Ig Nobel citation described Quayle as a "consumer of time and occupier of space" and lauded him "for demonstrating, better than anyone else, the need for science education".

Feedback is heartened to see educational vim spread from nation to nation. The sky, wherever that might be, is the limit.

Twisteddoodles *for New Scientist*


THE SCIENTISTS ON ME ARE USING MATH TO THEORISE YOUR WEIGHT.
HOW RUDE.
YOU THINK THAT'S BAD? THEY TOLD ME IM THE DENSEST PLANET.
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Bass notes

Andy Howe sings praise of a somewhat musical discovery about a fish that spends much of its time at the muddy sea bottom.

Does Andy Howe find joy in the details? And how! He says: "I draw your attention to 'Midbrain node for context-specific vocalisation in fish' (published in the journal *Nature Communications*) which concerns the distinctly fishy noises of Plainfin Midshipman, the species which is also known as 'Californian Singing Fish'. Blessed with a 'sonic swim bladder', they can communicate with modulated, trumpety hums or grunts. There's a double resonance here, as the lead author is A Bass."

"A Bass" is Andrew Bass, a professor of neurobiology and behaviour at Cornell University in New York. When not at sea in pursuit of fishes, A Bass spends time in his office, which is in Mudd Hall. A Bass, Feedback cannot help but note, steeps in nominative determinism.

Light amusement

Retired physician John Innes rallied to Feedback's call (9 December 2023) for first-hand testimony that refutes or confirms the old saying "the art of medicine consists mostly of amusing the patient while nature cures the disease".

He first sets the scene: "In the 1890s a Faroese/Danish physician, Niels Finsen, showed that UV light could cure tuberculosis (TB) of the skin. For this work Finsen was awarded a Nobel Prize in 1903. Finsen's original work used artificial UV light and this was widely used in TB treatment in the 1920s and 1930s.

"But it was already known that natural UV light was present in sunshine. This was one of the factors which promoted the development of sanatoria for TB treatment. Once the introduction of antibiotics in the 1950s had transformed treatment for TB, UV light treatment was consigned to history."

John then relates his experience in the 1980s as a physician in Birmingham, UK, specialising in infectious diseases: "I was asked to see a 17 year old who had recently started training as a nurse. At that time all new entrants to nurse training would be offered a vaccine against TB, if they hadn't already had it. In her case an ulcer appeared at the site of her injection and it gradually enlarged over two months to a width of about 8 cm. I advised a course of antibiotics. But she was going on holiday the next morning and didn't have time to collect a prescription. So I told her to put off her treatment and come back to see me in four weeks.

"She returned after spending two weeks sunning herself on a beach near Tangiers. The ulcer had healed and nothing more was needed. So, she amused herself while nature cured her disease."

Loop soup

What is loop soup? Hard to say. Hard to say concisely, that is.

Wojtek Furmanski and Adam Kolawa at the California Institute of Technology apparently injected the phrase into the physics world in 1987, in the middle of a 35-page paper called "Yang-Mills vacuum: An attempt at lattice loop calculus", published in the journal *Nuclear Physics B*.

They mention loop soup only once. These are their words: "The medium is still very far from the asymptotic 'loop soup', intractable by our methods."

That sentence may be inscrutable to anyone without a deep education in nuclear physics. Yet the phrase did catch on. Just 33 years later, Valentino Foit and Matthew Kleban at New York University wrote a paper called "New recipes for Brownian loop soups", which sounds positively possibly appetising. ▮

Marc Abrahams

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